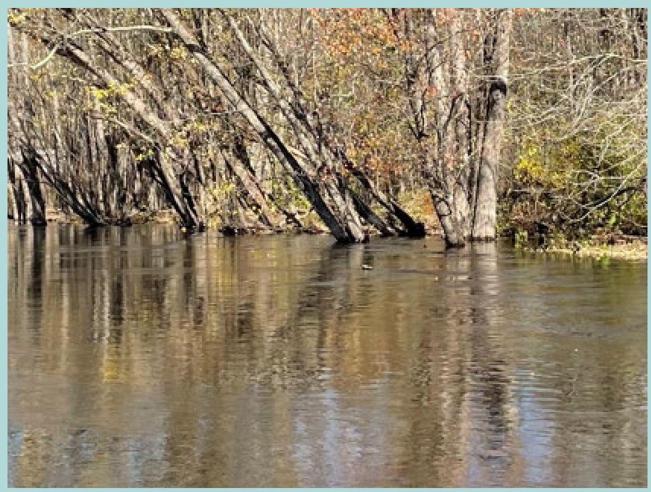
R-WD-22-03

PROTECTED INSTREAM FLOW STUDY REPORT



WARNER RIVER

June 2023

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List of Abbreviations

AEFOC	Alberta Environment Fisheries and Oceans Canada
cfs	cubic feet per second
cfsm	cubic per second per square mile
CWA	Clean Water Act
EPA	Environmental Protection Agency
°F	degrees Fahrenheit
ft	feet
ft^2	square feet
FTM	Floodplain Transect Method
GIS	Geographic Information System
GPS	Global Positioning System
HSI	Habitat Suitability Index
IFIM	Instream Flow Incremental Methodology
MVP	Merrimack Valley Paddlers
NH	New Hampshire
NHB	Natural Heritage Bureau
NHDAMF	New Hampshire Department of Agriculture, Markets, and Food
NHDES	New Hampshire Department of Environmental Services
NHDFL	New Hampshire Division of Forests and Lands
PHABSIM	Physical Habitat Simulation
RMPP	Rivers Management and Protection Program
RTE	Rare, Threatened, or Endangered
SI	suitability index
TFC	Target Fish Community
UCUT	Uniform Continuous Under Threshold
USDOI	United States Department of the Interior
USFWS	United States Fish and Wildlife Services
USGS	United States Geological Survey
USGS Gage	USGS gage at Davisville, NH (USGS Gage No. 01086000)
WSE	water surface elevation
WUA	Weighted Usable Area
YOY	young-of-year

Executive Summary

The New Hampshire Legislature created the Instream Flow Program in 1990, applying instream flow protections to the state's Designated Rivers. The goals of the Instream Flow Program are to maintain water for instream public uses, protect the resources for which the river or segment is designated, and regulate the quantity and quality of instream flow along designated rivers to conserve and protect outstanding characteristics.

To implement the program, the New Hampshire Department of Environmental Services (NHDES) determines the flow conditions in a stream that will protect the resources that are dependent on flow. New Hampshire has adopted regulations for the protection of instream flow on Designated Rivers (Env-Wq 1900). These regulations specify standards, criteria and procedures by which Protected Instream Flows shall be established and enforced. In accordance with the regulations, NHDES conducted a Protected Instream Flow Study on the Warner River and developed this study report, which includes proposed Protected Instream Flows. This report fulfills the requirement of determining protected instream flow criteria for the Warner River. The Protected Instream Flows identified in these studies will inform the Water Management Plan for the Warner River, which will describe how water users will operate to satisfy their water use needs while also maintaining protected flow conditions.

The Protected Instream Flow Study was completed by documenting instream public uses that could be affected by potential alterations in the flow regime of the river and by performing scientific assessments to determine the flows that are needed to protect the public uses. The studies were performed within the context of the Natural Flow Paradigm, which suggests that variability of flows within and between years, as related to the natural magnitude, timing, duration, frequency and rate of change of flows, is necessary to maintain or restore the native integrity of aquatic ecosystems.

The results of three primary assessments, including aquatic habitat, riparian habitat and recreation, provided the proposed Protected Instream Flows for the Warner River. The aquatic habitat study included a stratified-random study design, which was a robust and unbiased design, for evaluating the habitat needs of prominent fish species that make up the Target Fish Community identified for the river. The riparian habitat assessment was performed using the Floodplain Transect Method, whereby the riparian communities along the river were surveyed and their frequency of inundation evaluated. Lastly, the needs of flow-dependent recreation were identified by performing surveys and interviews of recreationalists, along with online research.

In general, the habitat needs of various species within the Target Fish Community were the primary factor for low-flow protection throughout the year, whereas the needs of riparian habitat provided more general guidelines for maintaining the frequency of higher flows. Flow-dependent recreation was documented on the Warner River, though protection of a combination of aquatic and riparian flows under the Natural Flow Paradigm would protect the flows for flow-dependent recreational resources on the Warner River. The Protected Instream Flows developed for the Warner River based on the studies are included in Table 1.

Table 1: Protected Instream Flows for the Warner River[1]

	Common	Common	Common	Common	Critical	Critical	Critical	Critical	Rare	Rare	Rare	Rare
Date Range	Common Flow (cfs)	Common Flow (cfsm)	Allowable Duration Under (days)	Catastrophic Duration (days)	Critical Flow (cfs)	Critical Flow (cfsm)	Allowable Duration Under (days)	Catastrophic Duration (days)	Rare Flow (cfs)	Rare Flow (cfsm)	Allowable Duration Under (days)	Catastrophic Duration (days)
December 1 – February 28/29	317	2.17	45	77	80	0.55	22	40	39	0.27	10	16
March 1 – April 30	1,062	7.27	26	44	148	1.01	13	27	109	0.75	7	11
May 1 – June 30	244	1.67	15	37	44	0.30	7	11	31	0.21	4	6
July 1 – September 30	76	0.52	30	71	11	0.08	14	24	6	0.04	8	15
October 1 – November 30	106	0.73	20	39	29	0.20	11	22	23	0.16	8	15

Key:
Green shaded columns mean Common.
Yellow shaded columns mean Critical.
Peach shaded columns mean Rare.

Retain Flood Frequencies:

- Inter-annual flow events of at least 400 cfs multiple times per year for emergent and riverine wetlands
- Annual flood frequency of at least 1,160 cfs for shrub scrub and seasonally/semi-permanently flooded floodplain forests
- 2-year flood frequency of at least 2,225 cfs for higher elevation floodplain forests

Optimum Recreational Boating Flows (Spring and Fall): Provide flow events of 565 cfs to 800 cfs

[1] Note: Flows provided are indexed to the USGS gage at Davisville, NH (USGS Gage No. 01086000), drainage area of 146 mi^2

1 Introduction

1.1 New Hampshire Instream Flow Program

The New Hampshire Legislature created the Instream Flow Program in 1990, applying instream flow protections to the state's Designated Rivers. The goals of the Instream Flow Program are to maintain water for instream public uses, to protect the resources for which the river or segment is designated, and to regulate the quantity and quality of instream flow along designated rivers in order to conserve and protect outstanding characteristics.

To implement the program, NHDES determines the flow conditions in a stream that will protect aquatic life, riparian ecosystems and recreational uses. New Hampshire has adopted regulations for the protection of instream flow on Designated Rivers (Env-Wq 1900). These regulations specify standards, criteria and procedures by which Protected Instream Flows shall be established and enforced. According to the regulation, NHDES shall conduct a Protected Instream Flow study and develop a study report that includes proposed Protected Instream Flows. The proposed flows are provided to the public for review and a public hearing is held on the study report and proposed flows before the commissioner issues a decision establishing the Protected Instream Flows for the Designated River. The Protected Instream Flow Study will:

- Identify and catalog all flow-dependent instream public uses on the Designated River listed under RSA 483:9-c, I and all designated uses under the federal Clean Water Act (CWA).
- Include an on-the-water stream survey of all flow-dependent instream public uses and designated uses under the CWA. The survey would directly observe, identify and catalog fish, wildlife, macroinvertebrates, plant and recreational uses.
- Be based upon scientific analyses using methods described in the *Report of the Instream Flow Pilot Program* (NHDES, 2015).

After the Protected Instream Flows are developed, water management plans are drafted that describe how water users will operate to satisfy their water use needs while also maintaining protected flow conditions and how dam owners will manage their dams to maintain flow downstream.

Protected Instream Flows were developed for the Warner River by following the regulations discussed above to protect instream flows on the Warner River for future aquatic, riparian, and human uses.

1.2 Natural Flow Paradigm

Protected Instream Flow rates were developed for the Warner River within the context of the Natural Flow Paradigm (Poff et al., 1997). This concept is based on evidence suggesting that variability of flows within and between years, as related to the natural magnitude, timing, duration, frequency and rate of change of flows, is necessary to maintain or restore the native integrity of aquatic ecosystems.

1.3 Warner River Background

1.3.1 Designation

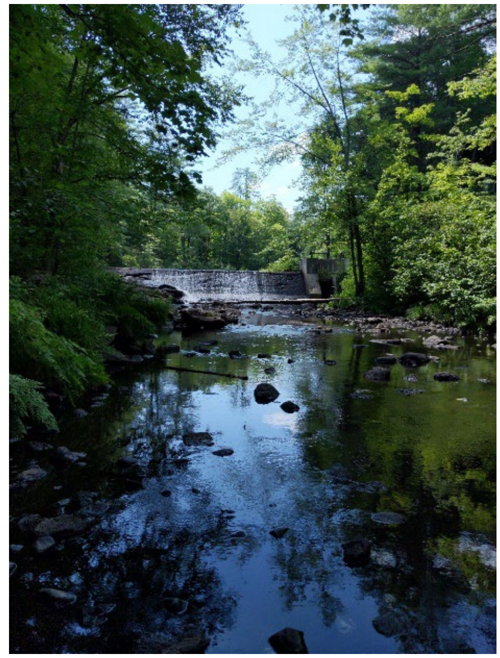
The New Hampshire Legislature created the Rivers Management and Protection Program (RMPP) within NHDES in 1988. The RMPP helps New Hampshire communities and towns protect a river. It allows for a wide range of uses for the river without adversely affecting the resources of the river. The Warner River was accepted into the RMPP as a designated river in 2018. The Warner River is an integral part of central New Hampshire's landscape, flowing through the five communities of Bradford, Sutton, Warner, Webster, and Hopkinton. The Warner River is designated for protection for 20.5 miles under the RMPP. The designated river begins at the confluence of the West Branch Warner River and Andrew Brook (the outlet of Lake Todd) in Bradford, continues 1.1 miles to the confluence of Hoyt Brook where it becomes the Warner River, and continuing about 19 miles to its confluence with the Contoocook River in Hopkinton. The river is classified as a Rural-Community River in its upper portion, a Community River in parts of Bradford and Warner, and a Rural River elsewhere.

1.3.2 General Description

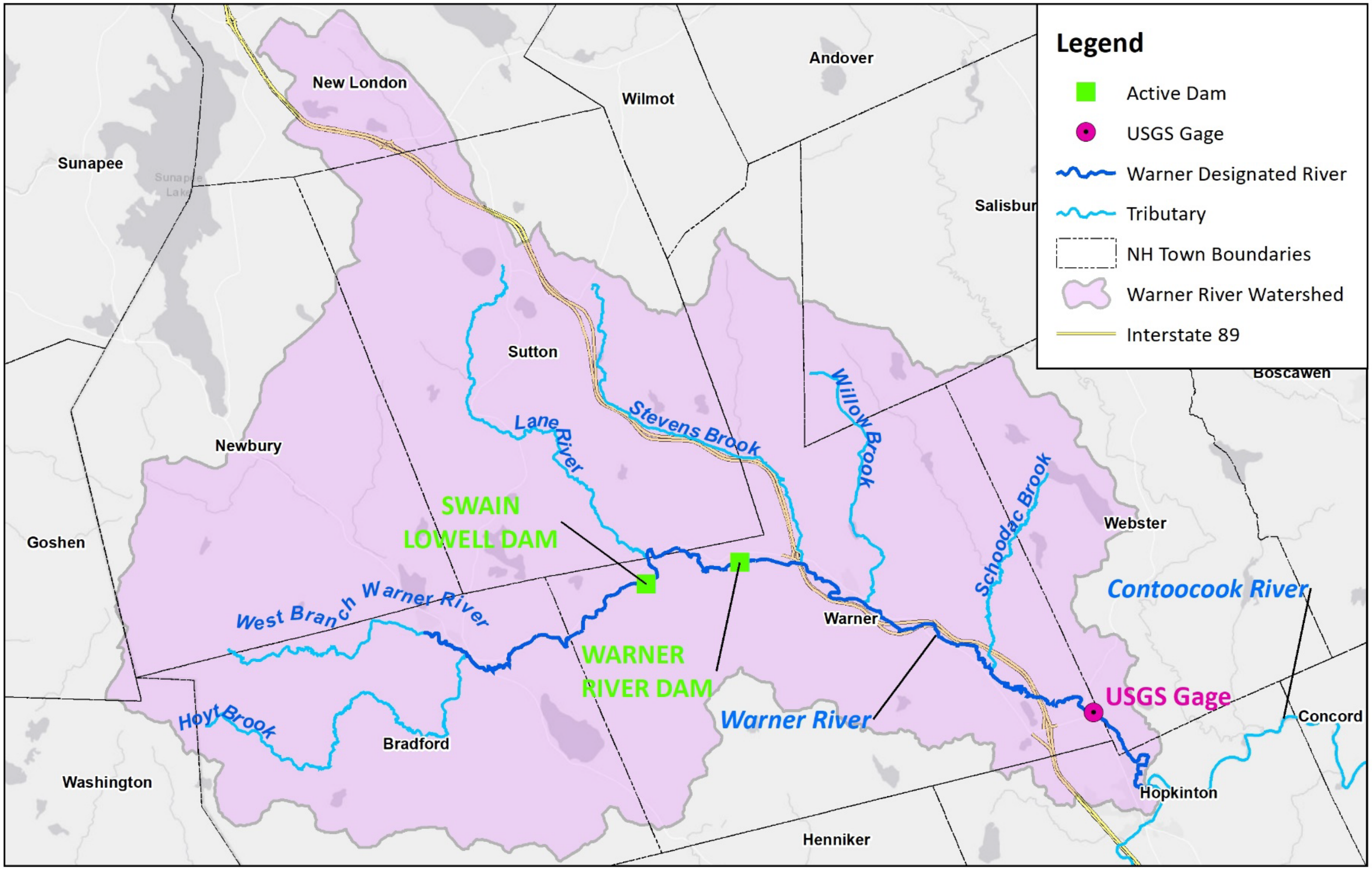
Warner River Near Route 103 in Warner

The Warner River flows from the confluence of the West Branch Warner River and Hoyt Brook in Bradford through the towns of Sutton, Warner, Webster, and Hopkinton to its confluence with the Contoocook River in Hopkinton, where it has a drainage area of approximately 149 square miles (Figure 1.3.2-1). The West Branch Warner River drains the southeastern portion of Mount Sunapee and flows from Newbury to its confluence with Hoyt Brook. Downstream of Hoyt Brook, the Warner River increases as it is joined by many small tributaries, including the Lane River, Stevens Brook, Willow Brook, and Schoodac Brook. The river gradient varies greatly throughout its course, with some portions characterized by backwater and slow-moving runs while cascades and rapids are present in other portions. The characteristics of the river as it flows through Warner are highly variable, and include impounded areas, flatwater, and rapids ranging from Class I to Class IV, depending on the flow. Much of the river below Warner Village is slow flowing, with one more area of whitewater before becoming slow and meandering for a short distance as it enters the Contoocook River. Throughout the River, several emergent bars in and around the river channel were observed, and dominated by plant species such as goldenrod, Joe Pye weed, sedges, and cardinal flower.

There are currently two active dams on the Warner River and nine dam ruins, most of which were used for mills that no longer exist. The two remaining dams include the Swain Lowell Dam located off of West Roby District Road in Warner, and the Warner River Dam just downstream of the Newmarket Road covered bridge. There are no active hydroelectric projects on the river. There is one active stream gage located on the river, USGS Gage No. 01086000 at Davisville, NH (USGS gage). The gage has a drainage area of 146 square miles and a period of record from 1939 to present. There are currently no active water withdrawals from the Warner River, though there are several registered public water systems that draw water from wells within the watershed (WRLAC, 2021). The largest public water system is the Warner Village Water District, which draws water from wells that are close to the river (NHDES, 2021).



Swain Lowell Dam



Protected Instream Flow Study Report
Warner River, NH

Figure 1.3.2-1:
Warner River Watershed

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1.3.2-1: Warner River Watershed

2 Occurrence of Protected Entities on the Warner Designated River

The protection goals of the Instream Flow Program are to maintain water for flow-dependent instream public uses, protect the resources for which the river or segment is designated, and to regulate water quality and quantity in designated rivers, in order to conserve and protect the river's outstanding characteristics. Specific categories of the instream public uses and outstanding characteristics and resources (collectively called protected entities in the Instream Flow Program) are described in RSA 483.

The Warner River's protected entities were identified by gathering readily available information and data, performing an on-stream reconnaissance survey, and through various data collection efforts along the river.

2.1 Aquatic Organisms

The Warner River is known to support a variety of native resident fish species (Table 2.1-1). Additionally, non-native species such as largemouth bass (*Micropterus salmoides*) and smallmouth bass (*Micropterus dolomieu*) have been introduced to and developed populations within the river system. New Hampshire Fish and Game (NHFG) also stocks brook trout (*Salvelinus fontinalis*), brown trout (*Salmo trutta*), and rainbow trout (*Oncorhynchus mykiss*) in the Warner River and several tributaries each year, and several tributaries contain self-sustaining populations of brook trout. The fish species present include fish with a range of thermal tolerances, though the main stem river typically becomes too warm for summertime persistence of several coldwater fish species that would need to seek cooler water in tributaries or groundwater inflows.

Diadromous fish species that historically migrated upstream through the Merrimack River and utilized habitats within the Warner River that are currently restricted by the presence of dams, yet small numbers of American eel (Anguilla rostrata) are still reaching the Warner River. Though downstream dams on the Merrimack and Contoocook rivers continue to prevent runs of other native diadromous species such as American shad (Alosa sapidissima), blueback herring (Alosa aestivalis), alewife (Alosa pseudoharengus), Atlantic salmon (Salmo salar), and sea lamprey (Petromyzon marinus), ongoing and future restoration efforts could result in these species entering or re-entering the Warner River

Freshwater mussel communities observed during on-stream reconnaissance surveys consist of large numbers of eastern elliptio (*Elliptio complanata*). Eastern elliptio is the most common freshwater mussel in New Hampshire where it is known to provide benefits to water quality given its capacity for water filtration (NHFG, 2022). Brook floater (*Alasmidonta varicose*), a NH Endangered species, has been historically identified in the towns of Webster and Hopkinton, but more research and observation would be needed to determine whether this species resides in the designated river (WRLAC, 2021).

Table 2.1-1: Comprehensive List of Resident Fish Species Native to the Warner River

Species	Habitat Use Classification	Pollution Tolerance	Thermal Regime
banded killifish (*Fundulus diaphanus*)	MG	T	Warm
banded sunfish (*Enneacanthus obesus*)	MG	M	Warm
blacknose dace (*Rhinichthys atratulus*)	FS	T	Eurythermal[2]
bridle shiner (*Notropis bifrenatus*)	MG	I	Warm
brook trout (*Salvelinus fontinalis*)	FS	I	Cold
brown bullhead (*Ameiurus nebulosus*)	MG	T	Warm
burbot (*Lota lota*)	FD	S	Cold
chain pickerel (*Esox niger*)	MG	M	Warm
common shiner (*Luxilus cornutus*)	FD	M	Eurythermal
creek chub (*Semotilus atromaculatus*)	FS	T	Eurythermal
creek chubsucker (*Erimyzon oblongus*)	FS	I	Eurythermal
fallfish (*Semotilus corporalis*)	FS	M	Eurythermal
golden shiner (*Notemigonus crysoleucas*)	MG	T	Eurythermal
lake chub (*Couesius plumbeus*)	FD	I	Cold
longnose dace (*Rhinichthys cataractae*)	FS	M	Eurythermal
longnose sucker (*Catostomus catostomus*)	FD	I	Cold
northern redbelly dace (*Phoxinus eos*)	MG	I	Warm
pumpkinseed (*Lepomis gibbosus*)	MG	M	Warm
redbreast sunfish (*Lepomis auritus*)	MG	M	Warm
redfin pickerel (*Esox americanus*)	MG	M	Warm
slimy sculpin (*Cottus cognatus*)	FS	I	Cold
spottail shiner (*Notropis hudsonius*)	MG	M	Eurythermal
tessellated darter (*Etheostoma olmstedi*)	FS	M	Eurythermal
white perch (*Morone americana*)	MG	M	Eurythermal
white sucker (*Catostomus commersonii*)	FD	T	Eurythermal
yellow perch (*Perca flavescens*)	MG	M	Eurythermal

*Notes: The species shown are considered native residents of the Merrimack River drainage in NH. For Habitat Use Classification – MG = Macrohabitat Generalist; FD = Fluvial Dependent; FS = Fluvial Specialist. For Pollution Tolerance – I = Intolerant; S = Sensitive (Moderately Intolerant); M = Moderate Tolerance; T = Tolerant.

[2] Eurythermal indicates that a species is able to tolerate a wider range of temperatures.

2.1.1 Target Fish Community

The Target Fish Community (TFC) for the Warner River was developed using fish community data from the best available reference rivers that would characterize a feasible and currently relevant fish community (Bain and Meixler, 2005). As such, the TFC model does not represent a historically “natural” community, but instead represents a community that would be expected to exist in the present time given relatively low direct anthropogenic impact on instream habitat. The TFC developed for the Warner River (Figure 2.1.1-1) was used for the development of protected instream flows for aquatic habitat on the river. Details on the development of the TFC are documented in Gomez and Sullivan Engineers (2018).

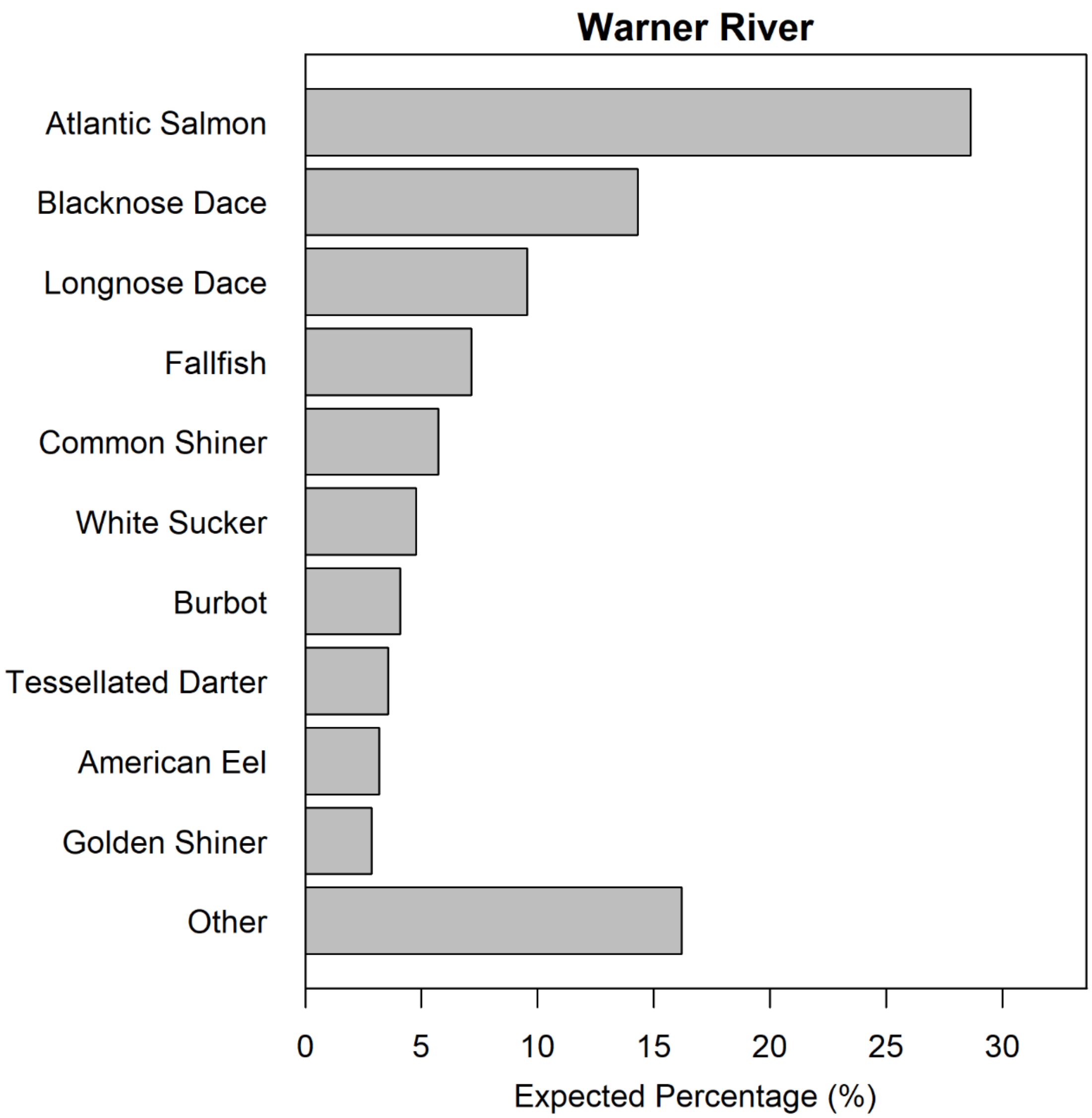

Figure 2.1.1-1: Target Fish Community for the Warner River

2.2 Riparian Habitat

The Warner River watershed supports a diverse range of habitats comprised of wetlands, forests and agriculture. Each of these habitats contains a wide variety of flora and fauna. The river corridor is largely undeveloped and contains several expansive freshwater forested/shrub wetland complexes, dominated by red maple, sugar maple, sycamore, elm, silky dogwood, ironwood, nannyberry, and wild grape. While the upper portion of the river corridor in Bradford is steep and characterized by rocky gorges, the lower portions through Warner and Hopkinton have mild gradients and large wetland complexes dependent on the river. Several natural communities and habitats for rare, threatened and endangered (RTE) species can be found in the riparian zone of the Warner River, many of which are dependent on flood flows from the Warner River periodically inundating the floodplain to provide these species with nutrients and organic matter.

2.2.1 Riparian Communities

2.2.1.1 Wetlands

Scrub-Shrub Wetland on the Warner River

The abundance of wetlands in the Warner River watershed is a key feature of significant value to the local ecosystem. Wetlands serve as important wildlife habitat that provide food, shelter, breeding areas and migration corridors for terrestrial and aquatic animals. Wetlands also serve as important recharge and discharge zones for stratified drift and bedrock aquifers and perform a variety of other key hydrologic functions including the filtration of pollutants and reduction of flooding and storm damage (US EPA, 2021).

There are a variety of wetlands found in the Warner River riparian zone. The standard definitions for different wetland types are included in Appendix A (Cowardin, et al., 1979). The most common types of riparian wetlands on the Warner River are palustrine forested (PFO) wetlands and palustrine scrub-shrub (PSS) wetlands. The total acreage for each different type of wetland encountered along the Warner River is summarized in Table 2.2.1.1-1.

Several forested and scrub-shrub PFO1/SS1E wetland complexes exist around the confluence of the Melvin River (the outlet of Lake Massasecum) and the Warner River. From here the river flows through Bradford, where it is characterized by steep gradient gorges and cascades, and minimal floodplain areas. As the river progresses through Sutton, Warner, and Hopkinton, it is almost entirely surrounded by large forested and scrub-shrub wetlands, dominated by dogwood, willow, and alder. Throughout the River, emergent bars in and around the river channel were observed, which were dominated by plant species such as goldenrod, Joe Pye weed, sedges, and cardinal flower.

Table 2.2.1.1-1: Riparian Wetlands on the Warner River

Wetland Classification	Description[3]	Area (acres)
R2USC	Riverine Non-Vegetated Aquatic Community	691.6
PFO1E	Palustrine Forested Broad Leaved Deciduous	223.6
L1UBH	Lacustrine Limnetic Unconsolidated Bottom Permanently flooded	188.3
PSS1/EM1E	Palustrine Scrub-Shrub Broad Leaved Deciduous/ Emergent Persistent	105.1
PSS1E	Palustrine Scrub-Shrub Broad Leaved Deciduous	84.81
R2UBH	Riverine Lower Perennial Unconsolidated Bottom	83.61
PFO1A	Palustrine Forested Broad Leaved Deciduous	68.28
PFO1/SS1E	Palustrine Forested /Scrub-Shrub Broad Leaved Deciduous	64.08
PEM1E	Palustrine Emergent Persistent	37.11
PEM1/SS1E	Palustrine Emergent Persistent/ Scrub-Shrub Broad Leaved Deciduous	27.5
R4SBC	Riverine Non-Vegetated Aquatic Community	22.05
PSS1/FO1E	Palustrine Scrub-Shrub/Forested Broad Leaved Deciduous	9.21
PEM1F	Palustrine Emergent Persistent	7.57
PFO1/4C	Palustrine Forested Broad Leaved Deciduous	7.39
PUBH	Palustrine Unconsolidated Bottom	7.38
PEM1/SS1Ed	Palustrine Emergent Persistent/Scrub-shrub	6.81
PSS3Da	Palustrine Scrub-Shrub Broad Leaved Evergreen	6.68
PSS1C	Palustrine Scrub-Shrub Broad Leaved Deciduous	6.58
PUBFb	Palustrine Unconsolidated Bottom	6.14
PFO1/SS1A	Palustrine Forested/Scrub-Shrub Broad Leaved Deciduous	4.86
PUBHh	Palustrine Unconsolidated Bottom	4.43
PSS1/FO1C	Palustrine Scrub-Shrub/ Forested Broad Leaved Deciduous	3.79
PSS1Eb	Palustrine Scrub-Shrub Broad Leaved Deciduous	3.2
L1ABH	Lacustrine Limnetic Aquatic Bed Permanently flooded	2.25
PSS1/EM1Eh	Palustrine Scrub-Shrub Broad Leaved Deciduous/Emergent Persistent	1.89
PSS1/EM1C	Palustrine Scrub-Shrub Broad Leaved Deciduous/Emergent Persistent	1.63
PFO1/SS1C	Palustrine Forested/Scrub-Shrub Broad Leaved Deciduous	1.55
PFO1/4A	Palustrine Forested Broad Leaved Deciduous	1.51
PEM1Eh	Palustrine Emergent Persistent	1.04
PFO1/5Fb	Palustrine Forested Broad Leaved Deciduous	0.93
PFO4C	Palustrine Forested Needle Leaved Evergreen	0.92
PFO4/1C	Palustrine Forested Needle Leaved Evergreen	0.84
PEM1/SS1F	Palustrine Emergent Persistent/Scrub-Shrub Broad Leaved Deciduous	0.8
PFO1/EM1E	Palustrine Forested Broad Leaved Deciduous/Emergent Persistent	0.39
PFO1Eh	Palustrine Forested Broad Leaved Deciduous	0.32
PUBHx	Palustrine Unconsolidated Bottom	0.26
PEM1C	Palustrine Emergent Persistent	0.25
PUBF	Palustrine Emergent Persistent	0.24
PABHh	Palustrine Aquatic Bed Permanently flooded, dike impoundment	0.21
PFO4E	Palustrine Forested Needle Leaved Evergreen	0.21
R2ABH	Riverine Shallow Open Water Community	0.11

[3] See Appendix A for full description including modifiers. See Cowardin et. al., 1979 for full description of wetland classifications.

2.2.1.2 Exemplary Natural Communities

Because the Warner River watershed contains a variety of habitats, from high gradient cascades to valley wetlands, a large array of plant life can be found on land and in the ponds, streams and rivers within the riparian zone. New Hampshire Natural Heritage (NHB) designates most occurrences of rare natural community types, and high-quality examples of more common community types as exemplary. Exemplary natural communities represent the best remaining examples of New Hampshire's biological diversity (NHDFL). Several types of exemplary natural communities are found within the Warner River Watershed (Table 2.2.1.2-1).

Table 2.2.1.2-1: Exemplary Natural Communities in the Warner River Watershed

Community	General Type	Town	Status
Drainage marsh - *shrub swamp system*	Palustrine	Bradford	Very High Importance
Inland Atlantic white cedar swamp	Palustrine	Bradford Sutton	Very High Importance Historical Record
Medium level fen system	Palustrine	Bradford Hopkinton	Very High Importance Very High Importance
Sandy pond shore system	Palustrine	Bradford	Very High Importance
Black gum - *red maple basin swamp*	Palustrine	Warner	Historical Record
Red maple floodplain forest	Palustrine	Webster	Historical Record
Temperate minor river floodplain system	Palustrine	Hopkinton	Historical Record
Chestnut oak forest/woodland	Terrestrial	Hopkinton	High Importance
Hemlock - beech - oak - pine forest	Terrestrial	Hopkinton	Historical Record
Hemlock forest	Terrestrial	Hopkinton	Historical Record

Note: Table adapted from WRLAC (2021) which cited the NH Natural Heritage Bureau, July 2020.

2.2.1.3 Observed Communities

Several wetlands and exemplary natural communities were observed on the Warner River during the on-stream reconnaissance survey. Several emergent communities were observed, dominated by goldenrod, Joe Pye weed, cardinal flower, tufted sedge, and royal fern. These communities are heavily reliant on flows from the Warner River. In the lower portion of the watershed, several forested and scrub-shrub wetland communities were observed, which were dominated by hemlock, beech, oak, pine, and red maple as well as dogwood, willow, and alder.

Emergent Wetland on the Warner River

2.2.2 Riparian Species

2.2.2.1 Rare, Threatened and Endangered Species

Rare, threatened and endangered (RTE) riparian plant species documented to occur in the Warner River watershed are primarily herbaceous. The RTE riparian plant species historically documented to occur in the towns along the Warner River are included in Table 2.2.2.1-1.

The USFWS Information for Planning and Consultation tool also identified the small whorled pogonia as a federally listed threatened species documented to occur in the Warner River watershed.

Table 2.2.2.1-1: RTE Riparian Plant Species Historically Documented on the Warner River

Species	Town	Status
American water-awlwort - *Subularia aquatica ssp. americana*	Bradford	NH Endangered
Sclerolepis - *Sclerolepis uniflora*	Bradford	NH Endangered
American ginseng - *Panax quinquefolius*	Warner	NH Threatened
Small whorled pogonia - *Isotria medeoloides*	Warner	US/NH Threatened, Highest Importance
Dragon's-mouth - *Arethusa bulbosa*	Webster	NH Endangered
Flat-stem pondweed - *Potamogeton zosteriformis*	Webster	NH Endangered, Historical Record
Giant rhododendron - *Rhododendron maximum*	Hopkinton	NH Threatened, Historical Record
Wild lupine - *Lupinus perennis ssp. perennis*	Hopkinton	NH Threatened, Historical Record

Note: Table adapted from WRLAC (2021) which cited the NH Natural Heritage Bureau, July 2020.

2.2.2.2 Observed Species

Rhododendron maximum (Go Botany, 2022)

Two state listed endangered species were observed on the Warner River during the on-stream reconnaissance survey, giant rhododendron (*Rhododendron maximum*) and sandbar willow (*Salix exigua*). One species with state-listed endangered varieties was observed on the Warner River, bluejoint (*Calamagrostis canadensis*). Giant rhododendron is a shrub found in wet forests and hemlock dominated swamps throughout the Northeast (Go Botany, 2022). Giant rhododendron on the Warner River was identified growing in two locations on the bank of the river, in hemlock-dominated forests. Sandbar willow is a relatively rare willow that is primarily found on the shorelines of major rivers in New England as well as in floodplains and man-made or disturbed habitats (Go Botany, 2022). Sandbar willow was identified in the upper portion of the designated Warner River. Bluejoint, or Canada reed grass, is found in a variety of habitats in New England. There are three varieties recognized, two of which are rare in New England *(langsdorfii* and *macouniana*) (Go Botany, 2022 and NHDFL, 2020). Bluejoint was identified on the Warner River, although the exact variety was not determined based on visual observation.

The trees stratum in the Warner River riparian zone was observed to be dominated by red maple (*Acer rubrum*), American hornbeam (*Carpinus caroliniana*), northern red oak (*Quercus rubra*), American elm (*Ulmus americana*), black cherry (*Prunus serotina*), sugar maple (*Acer saccharum*), silver maple (*Acer saccharinum*), American linden (*Tilia americana*), green ash (*Fraxinus pennsylvanica*), American beech (*Fagus grandifolia*), eastern hemlock (*Tsuga canadensis*), and American sycamore (*Platanus occidentalis*). The shrub stratum was dominated by silky dogwood (*Swida amomum*), fox grape (*Vitis labrusca*), white meadowsweet (*Spiraea alba*), nannyberry (*Viburnum lentago*), willow (*Salix sp.*), Asian bittersweet (*Celastrus orbiculatus*), and speckled alder (*Alnus incana*). The herb stratum was dominated by sensitive fern (*Onoclea sensibilis*), poison ivy (*Toxicodendron radicans*), royal fern (*Osmunda regalis*), Virginia-creeper (*Parthenocissus quinquefolia*), false nettle (*Boehmeria cylindrica*), blue-stem goldenrod (*Solidago caesia*), Canada goldenrod (*Solidago canadensis*), deer-tongue (*Dichanthelium clandestinum*), marsh fern (*Thelypteris palustris*), New York fern (*Parathelypteris noveboracensis*), small white American-aster (*Symphyotrichum racemosum*), and tall meadow-rue (*Thalictrum pubescens*).

Salix exigua *(Go Botany, 2022)*

Several invasive species, not native to New Hampshire, were also identified on the Warner River including Norway maple (*Acer platanoides*), garlic mustard (*Alliaria petiolate*), Japanese barberry (*Berberis thunbergia*), common barberry (*Berberis vulgaris*), Asian bittersweet (*Celastrus orbiculatus*), autumn olive (*Elaeagnus umbellate*), burning bush (*Euonymus alatus*), glossy false buckthorn (*Frangula alnus*), Japanese knotweed (*Reynoutria japonica*), and multiflora rose (*Rosa multiflora*). Of these species, Asian bittersweet and Japanese knotweed were the most prevalent.

A comprehensive list of all plant species identified on the Warner River during the on-stream reconnaissance and subsequent field surveys is included in Appendix B.

2.3 RECREATION

2.3.1 Methods for Documenting Occurrence of Recreation

Occurrence of flow-dependent instream human uses, including boating, fishing and swimming, were assessed using a combination of recreational surveys, online outreach and field observations. Recreational sites on the Warner River were identified during the onstream reconnaissance. Most recreational sites were informal pull-offs and trails along the river. More heavily visited recreational areas along the Warner River include Bradford Pines in Bradford and Riverside Park and Bagley Field in Warner.

Recreational surveys were performed seven times along the length of the river, with visits to all sites identified during the onstream reconnaissance (Table 2.3.1-1). Survey dates were chosen to capture several flow conditions and different seasons, when possible. Based on preliminary review of boating information available for the Warner River, boating would not typically occur during low flow periods (e.g., summer) unless a moderate to high flow event occurred. Surveys were conducted to document the occurrence of boating, fishing, and swimming on the Warner River, as well as to determine flow preferences for each recreation type. It should be noted that the COVID-19 pandemic was occurring during the recreation survey.

Table 2.3.1-1: Recreational Survey Dates and Flow Conditions

Date	Day	Weather	Air Temp (°F)	Flow at USGS Gage (cfs)	Gage Height (ft)
6/19/2020	Friday	Sunny	87	21.6	3.24
10/3/2020	Saturday	Partly Sunny	59	44.6	3.53
10/18/2020	Sunday	Partly Sunny	40	200	4.43
12/4/2020	Friday	Overcast	49	413	5.09
3/21/2021	Sunday	Sunny	59	277	4.71
4/3/2021	Saturday	Sunny	42	524	5.39
5/1/2021	Saturday	Sunny	50	569	5.49

In addition to formal recreational surveys, any instances of boating, swimming, and fishing that were observed on the Warner River during aquatic and riparian habitat assessment field efforts were documented during various field visits seasonally and under different flow conditions. Additionally, for boating, a search of the Merrimack Valley Paddlers (MVP) group on Facebook was conducted to determine when boaters were likely to visit the Warner River. If a video, photo, or post was made stating that someone had paddled the Warner River, the date was recorded and the flow and gage height at the USGS gage were determined. A summary table of observations of recreation and scans of the recreation field surveys are included in Appendix C.

2.3.2 Documented Occurrences of Recreation

Several occurrences of recreation were documented on the Warner River during the on-stream reconnaissance, recreational surveys, and during other field efforts related to the fish habitat and riparian vegetation assessments. Recreation was documented to occur both at private residences along the river and public access points including Riverside Park, Bagley Park, and the Waterloo Covered Bridge. Specific occurrences of boating, fishing, and swimming are discussed in the sections below.

2.3.2.1 Boating

Several instances of whitewater boating were documented on the Warner River. During the recreation surveys, four white water paddlers were surveyed during a spring flow which occurred in May of 2021. These paddlers were paddling the run between Melvin Mills Road and West Roby District Road. In addition to recreation surveys, the search of the MVP Facebook group showed that paddling is popular on the Warner River, with numerous posts dating back to 2014. Paddling mostly occurs during the spring and fall months, with between one and four posts each year since 2014. The focus on spring and fall months is likely due to the better likelihood of suitable boating flows, which are typically higher than what occurs during the summer months. Groups of boaters ranged in size from one to nine people with three people being the most common. The most popular section to paddle is from Melvin Mills to the Waterloo Covered Bridge, with some groups venturing past the bridge into Warner.

2.3.2.2 Fishing

Angling occurs on the Warner River, though it is not as popular as some other fishing destinations in New Hampshire. Angling was documented to occur on the Warner River, and a total of five anglers were identified during field surveys. One angler was documented at Riverside Park and three anglers were documented at the Waterloo Covered Bridge in June of 2021. One angler was documented at Dustin Road in April of 2021. Though angling occurs on the Warner River, it was not identified as a flow-dependent resource given that anglers would typically be targeting specific species during times of the year when fishing is typically best for those species. It is also anticipated that, under the natural flow paradigm, protected flows that provide habitat for a variety of game and forage fish species would also satisfy the needs of anglers.

2.3.2.3 Swimming

Swimming occurs on the Warner River most commonly at private residences along the river as well as at Riverside Park in Warner. During field surveys, swimming was documented at the West Joppa Road covered bridge where three swimmers were surveyed in June of 2020. Swimming was also documented at a private residence off of West Roby District Road during the on-stream reconnaissance in August of 2020, where four swimmers were identified. Swimming was not documented during and subsequent site visits at any public access points, however several private docks and river access points were identified during the on-stream reconnaissance. Swimming occurs during warm, low-flow periods in deep, slow, or impounded areas that are not substantially affected by changes in flow conditions. Therefore, swimming was not considered to be a flow-dependent resource on the Warner River.

3 Methods for Determining Protected Instream Flows

Protected flows were developed for specific flow-dependent instream uses, including aquatic organisms that reside in the river, riparian wildlife and vegetation and human recreational uses. Each of these three groupings were assessed using different methods. Aquatic organism habitat was assessed using the Instream Flow Incremental Methodology (IFIM). The Floodplain Transect Method (FTM) was utilized to assess riparian habitat. The FTM was adapted from survey methodologies developed at the University of Massachusetts, Amherst (Jackson, unpublished, as cited by NHDES 2009). Recreational uses were identified using surveys and online research.

3.1 Aquatic Habitat

Aquatic habitat in a river can be described using a combination of macrohabitat, mesohabitat and microhabitat variables. Macrohabitat refers to broad river characteristics impacting fish survival and movement such as food supply, predation, water temperature, and water quality. Mesohabitat refers to habitat types such as pools, riffles and runs. Microhabitat represents specific physical characteristics of a location within a river, such as slope, width, substrate, cover and the variation of depth and velocity with flow.

In general, a fish species or one of its life stages prefers a particular mesohabitat type because the microhabitat characteristics that make-up the mesohabitat are within its preferred range for a given species and life stage. For example, one species may prefer faster water with a rocky substrate, such as a boulder run, while another species prefers slower water with silt or mud substrates, such as a pool. These microhabitat conditions of depth and velocity are not static; they vary with streamflow. Too much or too little flow through the riffle or pool may push the velocities and depths outside the preferred limits or tolerances of a particular species or life stage.

The IFIM is a process for analyzing instream flows using field-measured microhabitat variables within several mesohabitats and hydraulic engineering models to derive habitat versus flow functions for certain aquatic organisms and life stages. The methodology is based on the premise that aquatic organisms prefer a certain range of depths, velocities, substrates and cover types, which are dependent upon the species and life stage and that the availability of these preferred habitat conditions varies with streamflow. The IFIM was developed in the late 1970s to quantify available habitat based the relationship between incremental changes in water flow and habitat (Bovee, 1982). The Physical Habitat Simulation (PHABSIM) model was developed in conjunction with the IFIM to complete the necessary hydraulic and habitat calculations required for IFIM analyses (USDOI and USGS, 2001). Field data were collected on the Warner River to obtain the necessary measurements required for the PHABSIM model to determine protected instream flows for aquatic habitat in the river.

In general, protected instream flows for aquatic habitat were developed by:

- Mapping mesohabitats along the entire designated river.
- Identifying reaches that contain similar habitat characteristics.
- Selecting study transects based on a stratified-random design.
- Collecting microhabitat and hydraulic data at study transects.

- Selecting evaluation species and Habitat Suitability Indices (HSI).
- Developing hydraulic-habitat models for the designated river.
- Converting flow timeseries data to habitat timeseries data for each species and life stage within relevant bioperiods.
- Analyzing habitat timeseries data for each species and life stage within relevant bioperiods.

Each of these steps are outlined below in greater detail.

3.1.1 Mesohabitat Mapping

Aquatic mesohabitats, including pools, riffles and runs, were mapped for the entire designated Warner River. Each mesohabitat unit was delineated using a field tablet with the ArcGIS Field Maps application and an internal GPS. For each habitat unit, additional field data such as dominant substrate, secondary substrate, maximum depth, average depth and wetted width were collected. Extensive photographic documentation was also collected throughout the on-stream reconnaissance survey.

3.1.2 Reach Identification

The mesohabitat data collected in the field were processed in ArcGIS to determine the length of each mesohabitat segment. Reaches of the river containing different habitat characteristics were identified based on locations where abrupt and/or substantial changes occurred in the frequency of certain mesohabitat types, substrates, and the size of the stream channel.

3.1.3 Study Design and Transect Selection

Reaches appropriate for aquatic habitat were identified based on their potential to provide meaningful results to the Protected Instream Flow Study. These reaches contained a high proportion of free flowing (e.g., non-impounded) habitats. Reaches with a high proportion of backwatered areas were not considered to be suitable given that impounded habitats (natural or manmade) would not be as sensitive to changes in flow relative to free-flowing reaches.

Once the study reaches were identified, a stratified-random design was implemented to select study sites in an unbiased manner. Transects for microhabitat measurements representing the primary mesohabitats within each reach were selected randomly.

3.1.4 Microhabitat and Hydraulic Data Collection

Microhabitat measurements, including depth, velocity, substrate type[4], instream cover[5], percent embeddedness[6] and bed elevations were collected across the river at the representative transects. The slope of the river at each transect was measured by surveying a longitudinal profile (up-and-down river)

[4] Substrate refers to the material in the channel such as sand, gravel, boulder, etc. Substrate is an important variable as certain species and life stages of fish prefer different substrate types.

[5] Instream cover includes velocity refuges such as large or small boulders allow fish to seek refuge from high water velocities.

[6] Percent embeddedness refers to the amount of fine material in interstitial spaces between the dominant substrate.

in the vicinity of the transect. Water level recorders set to record depth on 15-minute intervals were installed and surveyed at all transects and remained in place through a range of flow conditions.

Pre-marked ropes were extended along each transect and were anchored at fixed permanent locations on the riverbanks, above the estimated bankfull elevation where possible. The relative positions of these anchor points and temporary benchmarks were surveyed using a Total Station. Channel characteristics that are not flow-dependent, including substrate, instream cover, percent embeddedness, slope, bankfull elevation, and bed elevation were measured once, during the first field effort. Channel bed and bank elevations (to the nearest 0.01 ft) were collected at a series of points 1 foot apart (referred to as verticals) along each transect to develop stream cross-sectional profiles, using a Total Station referenced to the local transect datum. Substrate, percent embeddedness, and cover data were also collected at the same verticals as the bed elevations. Channel slope was estimated by measuring several bed elevations with the Total Station approximately 500 feet up and downstream of each transect. Photographs of each transect were also collected (Appendix D).

Depth, velocity, and water surface elevation, which are flow-dependent, were measured during three different flow conditions so that the PHABSIM hydraulic models could accurately characterize a wide range of flows. Table 3.1.4-1 shows a summary of the dates and flow conditions of the field measurement efforts. Field data for each event was collected over a two-day range.

Table 3.1.4-1: Summary of Field Data Collection River Flows

Field Data Collection Dates	Range of River Flow at USGS Gage	Average River Flow (cfs)
6/9/2021 – 6/10/2021	56.2 cfs to 59.7 cfs	58.5 cfs
8/12/2021 – 8/13/2021	161 cfs to 175 cfs	167 cfs
8/15/2022 – 8/16/2022	9.36 cfs to 11 cfs	10.5 cfs

Flow measurement dates were largely chosen due to what flow events were available during the study period. In general, the field-measured flows provide an overall good range of calibration flows to be input into the hydraulic model. While total river flow changed somewhat over the course of each field effort, the river was stable during measurements at each location. Depth and velocity were measured using a digital flow meter and wading rod set-up or an Acoustic Doppler Current Profiler (ADCP). These measurements were used as inputs into the hydraulic and habitat model as well as to estimate streamflow during the measurement. Water surface elevation was measured both using a rod and level and obtained from the water level recorders, which were both referenced to the local transect datum.

3.1.5 Habitat Suitability Indices for the Target Fish Community

Evaluation species for the PHABSIM habitat model were selected based on the TFC for the Warner River (Figure 2.1.1-1). All fish species with greater than 10% of the TFC were chosen for analysis, though fallfish were also included even though they did not meet the 10% criteria in order to evaluate habitat of a nest-building cyprinid species. Additionally, some anadromous fish species of interest were selected for evaluation given their historical reliance on flows in this river system, even if they are not currently present or abundant. Though freshwater mussels are an important aquatic species on the river, they were not chosen for analysis given their complex habitat requirements and life history, and generally limited knowledge of specific habitat suitability indices. However, maintaining habitat for other native aquatic species in their respective bioperiods, along with wetted area in the winter, would be protective of native mussel species.

Microhabitat suitability and preferences have been documented for several aquatic species in various studies over the last 40 years. Using the results of these studies, Habitat Suitability Index (HSI) curves have been developed for depth, velocity, substrate, and in some cases, cover. HSI curves describe suitability on a scale from 0 to 1 (called suitability index value). An HSI index value of 0 indicates no habitat value, whereas an HSI value of 1 indicates optimal habitat value. The HSI curves assign a range of velocities (ft/s) and depths (ft) a suitability index (SI) value between 0 and 1 to indicate a species/life stages preference for certain depths and velocities. HSI curves are also available for substrate preferences. Because substrate is a qualitative field determination (e.g., cobble, boulder, bedrock) a substrate coding system has been adopted to assign a numeric value to certain substrate, embeddedness and cover conditions (Table 3.1.5-1).

HSI curves that were used for the Warner River habitat model and the references for the studies they were obtained from are included in Appendix E.

Table 3.1.5-1: Substrate Coding System[7]

Code Type	Code Number	Description
Substrate Code	1	Roots, Snags, Undercut Banks
Substrate Code	2	Clay
Substrate Code	3	Silt
Substrate Code	4	Sand
Substrate Code	5	Small Gravel (<2")
Substrate Code	6	Gravel (2"-4")
Substrate Code	7	Cobble (4"-10")
Substrate Code	8	Small Boulder (10"-2')
Substrate Code	9	Large Boulder (>2')
Substrate Code	10	Bedrock
Substrate Code	11	Organic Detritus
Embeddedness Code	0.2	0-25%
Embeddedness Code	0.5	26-50%
Embeddedness Code	0.7	51-75%
Embeddedness Code	0.9	76-100%
Cover Code	0.03	Few Velocity Refuges
Cover Code	0.06	Abundant Velocity Refuges

[7] Example Field Code: 5.53 = Small Gravel (5), 26-50% Embedded (0.5), with Few Velocity Refuges (0.03)

3.1.6 Hydraulic Modeling

To develop habitat-flow relationships that capture a wide range of flows and to account for differing drainage areas and total flows measured in the field at each transect, a hydraulic model using MANSQ from the PHABSIM model was used to simulate hydraulic conditions for each transect using calibration data collected in the field.

MANSQ is a modeling approach that utilizes Manning's equation to predict water surface elevations, depths, and mean column velocities across each transect as a function of flow (USDOI and USGS, 2001). For transects that were heavily impacted by downstream backwater effects, the STGQ model within PHABSIM was used. The STGQ model utilizes a hydrologic rating curve to compute water surface elevations.

Velocities are computed using the Manning's equation or by regression between field measured velocities. For each transect, the field data were input into the model and used to compute depth, velocity, and wetted width at 27 additional flows not measured in the field, all standardized to the USGS gage.

3.1.7 Habitat Modeling

3.1.7.1 PHABSIM HABTAE Model

The results of the hydraulic model and the selected HSI curves for each evaluation species and life stage were used in the PHABSIM HABTAE model to develop habitat versus flow relationships. Each habitat cell at each simulated streamflow is evaluated for its habitat suitability for a particular species/life stage based on the HSI curves, fixed characteristics (substrate and cover), and the variable characteristics of the cell (depth and velocity). The PHABSIM methodology expresses habitat versus flow relationships as Weighted Usable Area (WUA) curves described in square feet of available habitat versus cfs of streamflow (USDOI and USGS, 2001).

The following equation was used to calculate WUA:

$$WUA = \frac{\sum_{i=1}^{n} WUA(I)}{L} \times L_{mac}$$

where: WUA(I) = Weighted Usable Area in cell (I);
n = Total number of cells in the reach;
L = Total length of the study reach; and
L_{mac} = Length of stream, which is represented by the reach, with suitable macrohabitat conditions.

The individual cell WUA(I) was calculated as follows:

$$WUA(I) = CF(I) \times Area(I)$$

where: Area(I) = Surface area of cell(I); and
CF(I) = Compound Function Index for cell(I)

The Compound Function Index, CF(I), was calculated as follows:

$$CF(I) = SI_V \times SI_D \times SI_S$$

where: SI_V = Suitability Index for Velocity;
SI_D = Suitability Index for Depth; and
SI_S = Suitability Index for Substrate/Cover.

The WUA was then computed for each cell and summed for each transect at each flow. The WUA from the representative transects within each reach were then multiplied by the length of the river that they were chosen to represent and the results from each reach were summed to develop a total WUA for the river.

3.1.7.2 Winter Habitat Assessment

Habitat for fish and aquatic life during the winter does not typically conform to the HSI curves, which typically apply to warmer bioperiods (e.g., when most foraging and growth occurs) and spawning bioperiods. However, wetted area is often considered to be a suitable habitat metric for winter aquatic habitat (AEFOC, 2007). Wetted width for each modeled flow at each transect was averaged for each mesohabitat that the transect represented. Average wetted width for each mesohabitat was then multiplied by length of that mesohabitat to develop wetted area versus flow relationships. The flow timeseries was converted to a wetted area timeseries for the habitat timeseries analysis during the winter bioperiod.

Even in the absence of detailed species-specific habitat data for winter conditions, maintaining wetted area will be protective of aquatic species during the winter months. This method is also advantageous because the relationship between wetted area and discharge remains constant assuming consistent channel morphology over time.

3.1.8 Habitat Timeseries Analyses

3.1.8.1 Evaluation of Long-Term Flow Dataset

Daily flow data for the Warner River were compiled by NHDES from 1950 to 2017.[8] The dataset was evaluated to determine whether any modifications were necessary to avoid historical effects that would have been inconsistent with the natural flow paradigm (e.g., were there any flow modifications to the river that would have affected the data on a daily time step). Given the lack of large storage dams, or major withdrawals that would have affected the gage data historically and currently, no modifications to the flow dataset were needed for further analysis.

3.1.8.2 Establishment of Bioperiods and Representative Species/Life Stages

The boundaries of bioperiods were determined from hydrologic patterns that occur over the course of a year, based on statistics (e.g., percentiles) from a long-term flow dataset. The representative species and life stages for each bioperiod were chosen based on the life history of prominent species from the

[8] Note: Gaps in the dataset from 10/01/1978 through 9/30/2001 had been filled by NHDES using the QPPQ Transform Method (Fennessey, 2019; Fennessey, 2018a; Fennessey 2018b).

TFC along with diadromous fish with historical habitat in the river. For bioperiods without specific species, appropriate metrics such as wetted area (winter) and water level (spring freshet) were chosen to be representative of habitat for those bioperiods.

3.1.8.3 Development of Habitat Timeseries

Within each bioperiod, the flow timeseries was converted to habitat for each of the target species and life stages (or other habitat parameters) using the habitat versus flow relationships from the habitat models.

3.1.8.4 Identification of Habitat Stressor Thresholds

Habitat stressor thresholds can be defined by evaluating the magnitude and duration of habitat limitation events. A habitat limitation event occurs when a specific quantity of habitat remains below a predefined threshold for a continuous period. Habitat limitation events that occur over longer periods have greater impacts on aquatic species and communities; these types of extended events occur at a lower frequency than brief periods when habitat may be limited.

To evaluate both magnitude and duration of habitat limitation events, Uniform Continuous Under Threshold (UCUT) curves were developed for each habitat timeseries developed for each bioperiod.[9] For habitat metrics that were a measure of area (e.g., WUA), the curves were standardized to the percentage of maximum habitat available based on the habitat models.

From the UCUT plots, which contain a series of curves, common and less common habitat limitation events can be distinguished based on the cumulative durations, the shape, and distances between the curves. Interpretation of these patterns can be generalized as follows:

- The curves in the left portion of the graph depict rare events.
- The horizontal distance between curves indicates the change in frequency of events associated with changes in habitat amounts.
- Steep curves represent little change in event frequency given differences in continuous durations, whereas inflection points reflect a rapid change in frequency of continuous durations.

Rare, critical, and common habitat levels were identified using the following set of rules:

- Rare: The first curve to contain portions that stand out from vertical. This may or may not be the first curve on the plot. This threshold would be exceeded most of the time within the timeseries dataset. If there is a cluster of curves preceded by a gap to the right, the right-most curve was chosen as the threshold.

[9] The UCUT method was developed as a modification to CUT curves (Capra, Breil and Souchon, 1995). The primary difference between the UCUT and CUT curves, is that the UCUT curves include points along the lines for all continuous durations, which results in vertical portions of the curves where specific duration values did not occur in the timeseries.

- Critical: The first curve that occurs beyond (to the right side of the plot) a gap after a cluster of curves. Below this point, if habitat were to become more limited, it would descend relatively rapidly to the rare level.
- Common: The first curve beyond the next gap in the curves, to the right of the critical level. Depending on the shape of the curves, this level may also be identified as curves that are no longer exhibiting the vertical nature that the rare and critical levels tend to exhibit, particularly at longer continuous durations.

For each threshold level, continuous durations were identified as:

- Persistent: The lowest convex inflection point along the curves. The curves begin to steepen above this point, which indicates a low frequency of longer-duration events.
- Catastrophic: A higher inflection point, above which the curve becomes primarily vertical. Above this point, durations are so high that they occur extremely infrequently, on a decadal scale.

In addition to using the rules above for identifying habitat level and duration thresholds for specific curves, it is important to note that the underlying patterns for surrounding curves were also visualized, with the underlying goal of delineating the primary regions for habitat thresholds along the continuum of both axes using the contours of the plot.

3.2 Riparian Habitat

3.2.1 Floodplain Transect Method for Riparian Vegetation

Protected instream flows for riparian flora and fauna and exemplary communities found in the floodplain and channel of the Warner River were assessed using the Floodplain Transect Method (FTM). This method involves surveying representative transects across the river channel and floodplain for resident flora and botanical species and evaluating inundation at various water levels to determine the flows that inundate these species or communities.

3.2.1.1 Transect Selection

The locations of the transects were chosen based on the presence of key wetland habitats and riparian species that were found during the reconnaissance. The transects spanned the entire river channel and much of the floodplain, to develop flow requirements for wetlands, floodplains and channel habitats and their associated flora.

3.2.1.2 Field Data Collection

Headpins were placed at both ends of the transect. When possible, these headpins were surveyed using a Real-Time Kinematic (RKT) GPS device.[10] Otherwise, headpin locations were recorded using a Bad Elf Global Navigation Satellite System Surveyor. Light detection and ranging (LiDAR) data collected by the Quantum Spatial in 2015 was obtained from NH GRANIT and used to establish the topography containing riparian habitats along each transect between the surveyed transect headpins. Primary vegetation types and species along each transect were documented using protocols consistent with NHDES survey methodologies (e.g., herbaceous stratum within a 1.5-meter swath along the transect, sapling/shrub stratum within a 5-meter swath along the transect, and tree stratum within a 10-meter swath along the transect). Breakpoints in vegetation type were surveyed along the transect using field tablet equipped with the ArcGIS Field Maps App developed by ESRI. Water level loggers were placed at each transect and were surveyed using the RTK GPS. Water level was recorded continuously, on 15-minute intervals, across a timespan that allowed the documentation of water levels at a variety of flow rates. Additionally, the transects were visited three times at various flow rates to confirm the levels of inundation.

3.2.1.3 Transect Analysis

Vegetation and topographic survey data were used to create cross-sectional profiles of each transect. The elevation of each breakpoint between vegetation types were denoted on the profiles. A continuous time series of water level logger data was used in conjunction with streamflow data from the USGS gage[11] to determine the flow at which each different vegetation type is inundated. The elevation of the vegetation type breakpoint was identified in the water level logger dataset and the corresponding discharge measured at the USGS gage during flow events were identified. Flood frequencies and magnitudes were calculated from the flow dataset.

[10] RTK GPS accuracy is dramatically degraded with the presence of overhead obstructions, such as trees. In these instances, RTK GPS was not used to survey headpins.
[11] Note: USGS data from December 15, 2021 through April 27, 2022 were still marked as provisional.

3.3 RECREATION

The results of the recreation surveys and online research, as described in Section 2.3, were evaluated to determine flow preferences for boating, fishing, and swimming. Surveys were tailored to each type of recreation and included questions on frequency and timing of visits to the Warner River, what sections are visited, how flows are monitored, and flow preferences.

4 Protected Instream Flow Study Results

4.1 Aquatic Habitat

4.1.1 Study Design

4.1.1.1 Mesohabitat Mapping Results and River Reach Delineation

Mesohabitat mapping of the designated Warner River was completed during the on-stream reconnaissance survey from August 10 through 13, 2020. River flows at the USGS gage were low, declining from 11.0 cfs to 8.4 cfs during the survey. Over twenty miles of habitat within the designated river were mapped during the on-stream reconnaissance survey. Lower-gradient run habitats were most abundant, at approximately 52.6% of the river length, followed by pool habitats (23.3%), backwater habitats (8.5%), pocket water habitats (5.7%) and riffle habitats (5.2%). Some other complex and/or braided channel habitats were identified, but they generally consisted of riffle, run, pool, and/or backwater habitats that occurred in combination along relatively short river segments.

Four reaches were delineated based on the mesohabitat mapping results (Figure 4.1.1.1-1). These reaches form the boundaries where river characteristics change on a relatively large scale. Within river segments, if needed, subreaches were defined where specific types of habitats within the reach occurred.

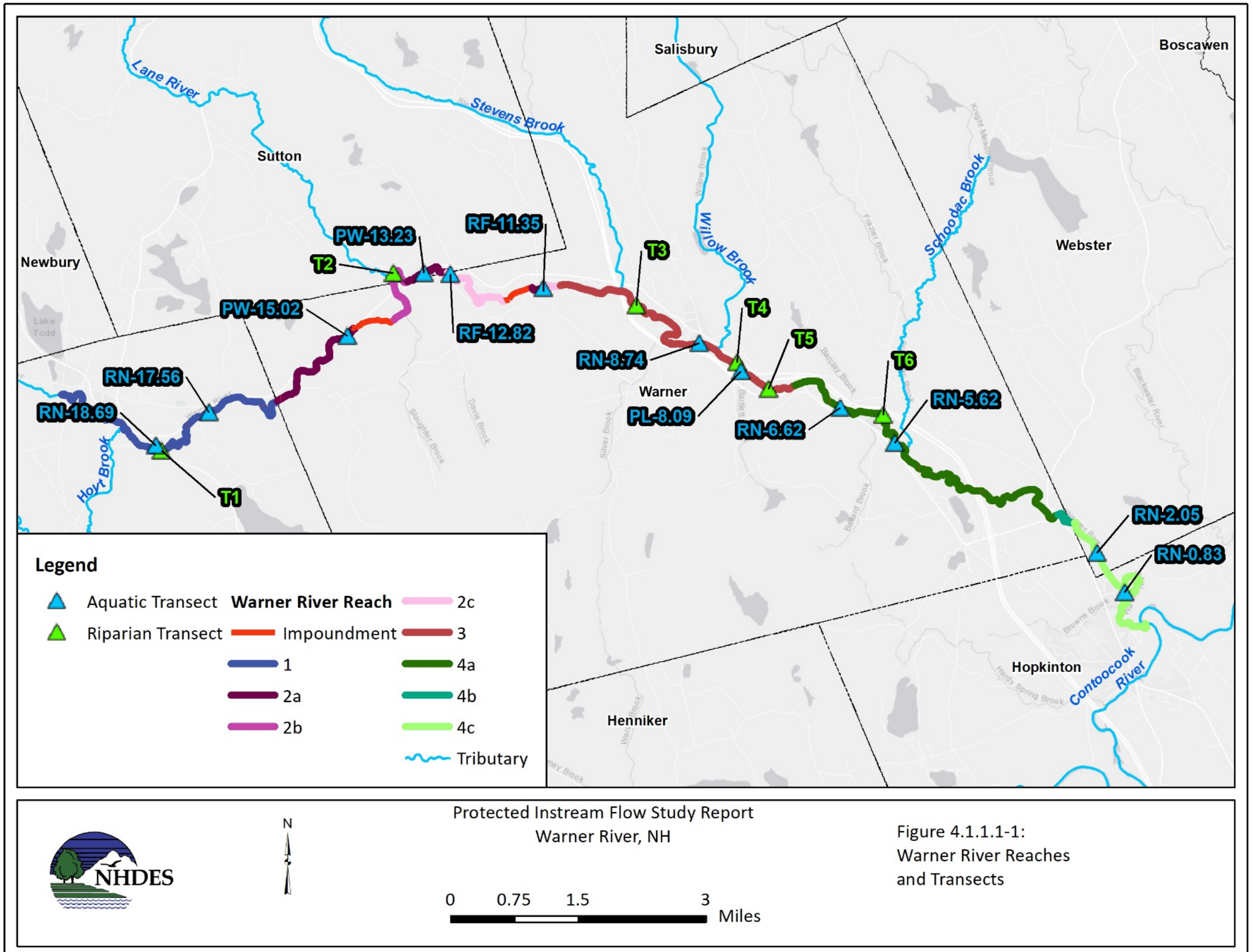

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Figure

4.1.1.1-1: Warner River Reaches and Transects

4.1.1.2 River Reaches

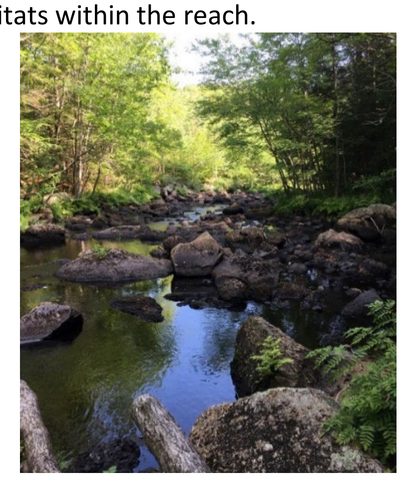
Reach 1

Reach 1 began on the West Branch Warner River, at the confluence with a tributary flowing in from Lake Todd and extends approximately 4.1 miles downstream. The total drainage area of Reach 1 ranges from 30 square miles at the upstream end to 59 square miles at the downstream end. This reach was characterized by primarily slow, sandy run habitat, and to a lesser extent, pool habitats. The river channel averaged 35 feet in width and 1.5 feet in depth. Instream cover in the form of large woody habitat and emergent/submergent vegetation were observed in several areas, and though overhead cover varied substantially, generally the extent of overhead cover was 25-50% or higher. Beaver activity was present in this reach, which resulted in some areas of backwater. Mussels were frequently observed, sometimes in large abundance, and spawning evidence of fallfish and centrarchids was observed in several areas.

Photograph in Reach 1

Reach 2

Reach 2 began a short distance upstream of the Melvin Road Bridge (near Stagecoach Loop) where substrates rapidly transitioned from the fine substrates in Reach 1 to large, boulder substrates. The total reach length was approximately 4.6 miles, ending at approximately 0.36 miles downstream of the Newmarket Road covered bridge. Mesohabitats in this reach followed an alternating pattern of very steep habitats followed by segments with low to moderate gradient habitats. Based on the different habitats of clustered habitats within this reach, three types of subreach habitats were delineated. There were also two relatively long riverine impoundments that were backwatered by dams within the reach. The drainage area in Reach 2 ranges from approximately 59 to 92 square miles. Though present in Reach 2, observations of mussels and evidence of fallfish and centrarchid spawning were less frequent relative to Reach 1 and were restricted to the low to moderate gradient habitats in Reach 2 where gravel substrates were most prominent. This was not surprising given the habitat preferences of these species and life stages. Habitats in Reach 2 were relatively diverse and were divided into three subreaches containing the three primary types of habitats within the reach.



Photograph in Reach 2A

Subreach 2a habitat accounted for approximately 2.3 miles of Reach 2 habitat and was characterized primarily by steep pocket water and riffle habitats with relatively large, boulder substrates. The channel here was comparable in width to Reach 1a at approximately 35 feet on average, but depths were more heterogeneous and shallower on average at approximately 1 foot deep. Overhead cover was still present at approximately 25-50% of the area over the channel, and instream cover was abundant in the form of boulders that provided velocity refugia and interstitial spaces.

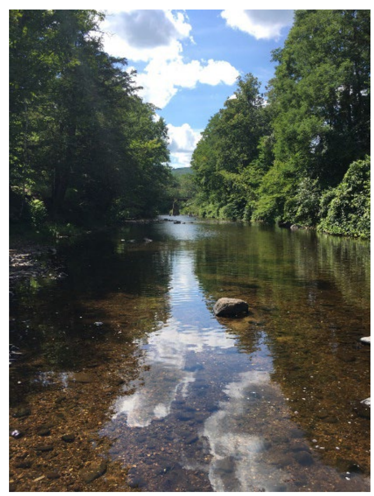
Photograph of Reach 2B

Subreach 2b habitat accounted for approximately 1.0 miles of Reach 2 habitat and was characterized primarily by low gradient and wide, gravelly run habitats, with some sandy substrates and backwater habitats also present. The channel here became relatively wide and shallow, with an average channel width of 53 feet, an average depth of 0.96 feet, and little overhead cover. Historic beaver activity in the form of remnant gravel bars that appeared to have been formed initially by beaver activity were a primary driver of the habitat characteristics.

Subreach 2c habitat accounted for approximately 1.3 miles of Reach 2 habitat and was characterized by gravel/cobble substrates within low to moderate gradient run and riffle mesohabitats. The wetted channel was moderately wide with variable but generally little overhead cover, averaging 49 feet in width with average depths of approximately 1.1 feet.

Reach 3

Reach 3 extends from the downstream extent of Reach 2 to the Route 103 bridge (downstream of the Village of Warner, upstream of Bagley Park). This reach contains nearly 3.8 miles of habitat, primarily consisting of gravelly runs and pools. The drainage area of this reach extends from approximately 92 to 122 square miles. The river channel is moderately wide, with an average width of 49 feet, an average depth of 1.3 feet, and relatively little overhead cover. Observations of mussels and fallfish nests were frequent in this reach, with the occasional bass or sunfish nest. Additionally, dense patches of short, submerged aquatic vegetation were observed in various locations within the river channel that appeared to provide valuable fish rearing habitat based on observations of large numbers of fry that were utilizing those areas.



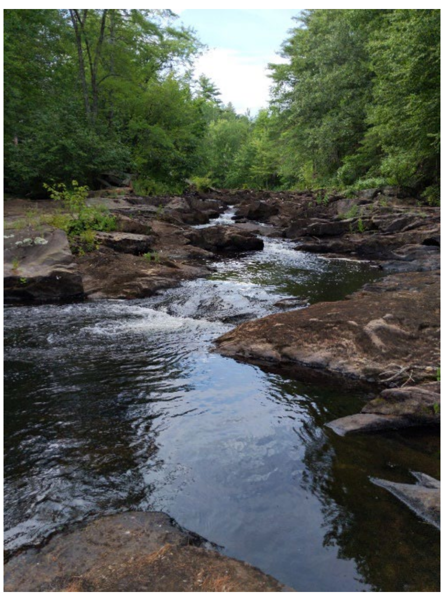
Photograph in Reach 3

Reach 4

Reach 4 extends approximately 7.6 miles from the downstream end of Reach 3 to the river mouth, at the confluence with the Contoocook River. The drainage area of this reach extends from approximately 122 to 149 square miles.

Photograph in Reach 4A

Subreach 4a habitat accounted for approximately 4.9 miles of Reach 4 habitat and was characterized primarily by low gradient run and pool habitats with sandy substrates that also contained some gravel. The river channel here was wide, averaging approximately 54 feet wide and 1.9 feet deep, with variable but primarily little overhead cover. Instream cover was limited to patches of scattered emergent



Photograph in Reach 4B

Subreach 4c habitat was located only downstream of the steep habitats in Subreach 4b and accounted for approximately 2.3 miles of Reach 4 habitat and was very similar to the habitat found in Subreach 4a. Subreach 4c habitats were wide (average wetted width of 55

and submergent vegetation and occasionally large woody debris. Beaver activity was prevalent in this reach, with several areas backwatered by beaver dams that spanned much or all of the river channel. Observations of mussels, fallfish nests, and centrarchid nests were frequent in this reach, which appears to provide large amounts of habitat for these species.

Subreach 4b habitat accounted for less than 0.4 miles of Reach 4 habitat and was characterized primarily by high gradient habitats consisting of bouldery pocket water and bedrock-driven step-pool areas. Wetted channel widths were relatively narrow at approximately 30 feet on average, and depths were variable but relatively shallow, at 0.8 feet deep on average. At the low flow observed, most wetted area was near the center of the channel where there was little overhead cover, though instream cover was generally good given the prevalence of boulders and deeper pocket habitats.
feet), shallow (average depth of 1.43 feet), low gradient, and were dominated by sandy runs with some pools. The primary reason for assigning different subreach habitat to this portion of the river, as opposed to considering it Subreach 4a habitat, was the potential for historic accessibility of this portion of Subreach 4 by certain diadromous species. Specifically, the high gradients and steps in Subreach 4b would have prevented passage of *Alosines* (shad and river herring), restricting them to the Subreach 4c habitats. Other diadromous species (e.g., American eel, Atlantic salmon, and sea lamprey) could have potentially entered and traversed the habitats within Subreach 4b and would not have been restricted to Subreach 4c habitats.

4.1.1.3 Representative Transect Selection

Representative aquatic habitat transects (n=12) were selected in Reaches 1 through 4 (Table 4.1.1.3-1 and Figure 4.1.1.1-1). Approximately 10.6 miles (58%) of the non-backwatered river length was represented by the habitat-hydraulic models. Generally, free-flowing riffles, pocket waters, and runs were considered the highest priority as these habitats tend to be more sensitive to changes in flow then pools. Transects were not selected from within habitats in short subreaches (e.g., Subreach 2b and Subreach 4b) because they accounted for a very small percentage of the study area and also contained habitat characteristics similar to larger subreaches where transects were selected.

Table 4.1.1.3-1: Summary of Representative Aquatic Habitat Transects

Reach/Subreach	Name[12]	Mesohabitat	Drainage Area (sq. mi.)
1	RN-18.69	Run	44.4
1	RN-17.56	Run	55.2
2a	PW-15.02	Pocket Water	61.0
2a	PW-13.23	Pocket Water	88.4
2a	RF-12.82	Riffle	90.0
2c	RF-11.35	Riffle	91.63
3	RN-8.74	Run	113.63
3	PL-8.09	Pool	118.66
4a	RN-6.62	Run	121.91
4a	RN-5.62	Run	124.81
4c	RN-2.05	Run	146.47
4c	RN-0.83	Run	146.96

[12] The name includes an abbreviation for the mesohabitat type, along with the distance in miles upstream of the river mouth.

4.1.2 Habitat versus Flow Relationships

Habitat versus flow relationships for each species/life stage are expressed as weighted usable area (WUA) measured in square feet versus flow (cfs) at the USGS gage. Habitat versus flow relationships for all species/life stages for the winter survival bioperiod are expressed as wetted area (ft^2) versus flow (cfs) at USGS Gage No. 01086000 in Davisville which has a drainage area of 146 mi^2. These relationships show available habitat on the Warner River as it related to flow in the river.

4.1.2.1 Species-Specific Relationships

WUA curves for each species/life stage evaluated in the IFIM study are included in Appendix F. Flows that were modeled ranged from 5 cfs to 405 cfs. WUA for most species/life stages peaked within this range, though American shad spawning and incubation continue to increase with flows beyond 405 cfs. Adult and juvenile life stages for most of the species have more habitat than spawning and incubation, likely due to very specific substrate preferences for this life stage (gravel).

Overall, the Warner River provides the most preferable habitat for fallfish and blacknose dace, due to the wide range in preferences for depth, velocity, and substrate for these species. In Reach 4, preferable habitat for Atlantic salmon and sea lamprey can also be found. The Warner River provides the least amount of habitat for river herring and American shad (due to the extent of their habitat being limited to Subreach 4c). Of the resident species, the Warner River provides the least preferable habitat for longnose dace, likely due to this species more specific preferences for depth, velocity, and substrate.

4.1.2.2 Wetted Area

Wetted area versus flow curves for all of the reaches individually and all reaches combined are shown in Figure 4.1.2.2-1. As discussed in Section 4.1.1.2, the Reach 4c curve was used for habitat analyses for American shad and river herring, the Reach 4 curves were used for habitat analyses for Atlantic salmon and sea lamprey, and all of the curves were used for all resident species. In general, the curves rise sharply from 5 cfs to 20 cfs, then become asymptotic. Beyond a certain flow, WUA often decreases. Wetted area continues to increase as flow increases and will never decrease like WUA, which means that wetted area will never be high-flow limited. However, increases in wetted area become marginal at the high range of modeled flows.

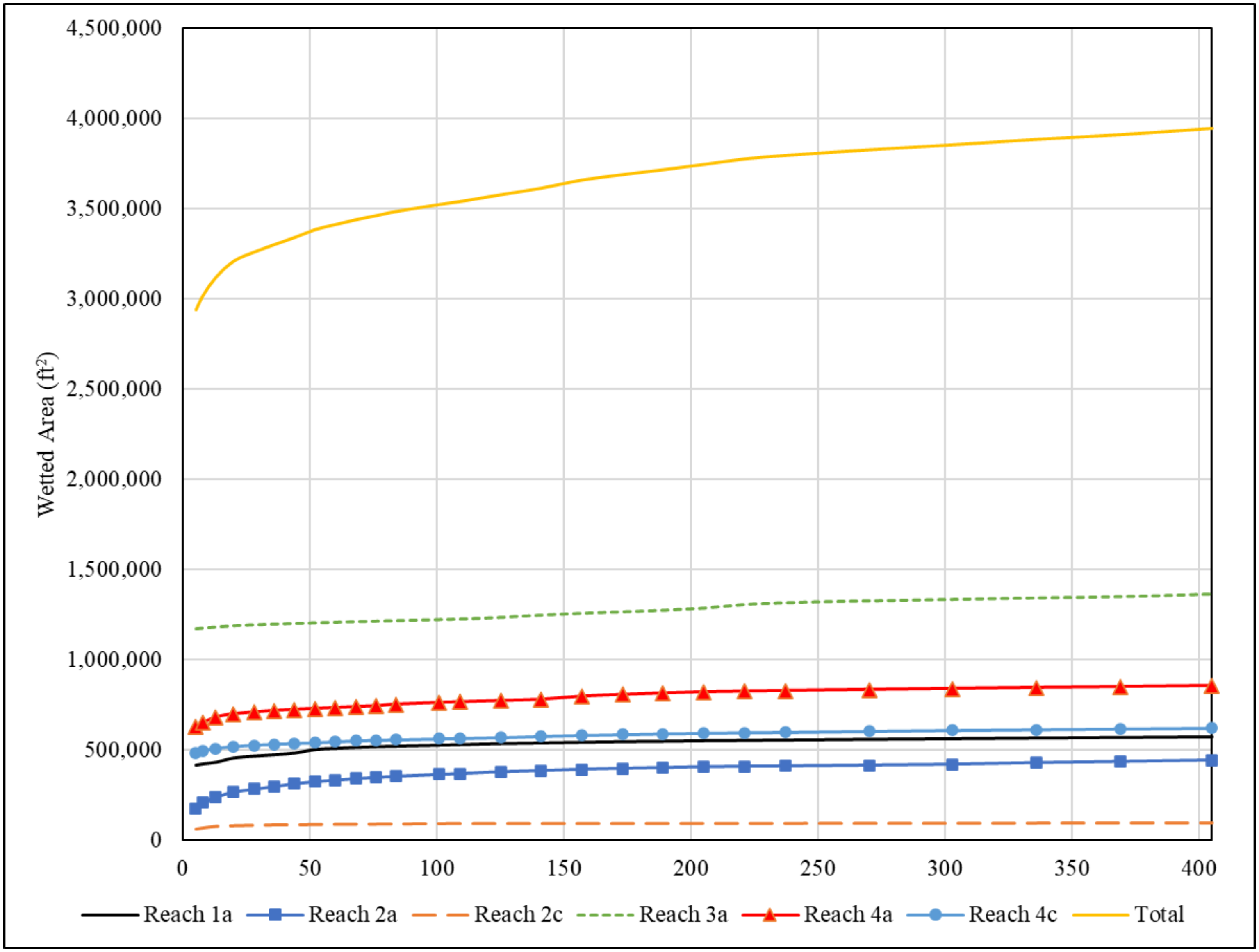


Figure 4.1.2.2-1: Wetted Area Curves

4.1.3 Habitat Timeseries Analyses

4.1.3.1 Bioperiods

Five bioperiods were identified on the Warner River based on the hydrology and the needs of the target aquatic species and life stages (Figure 4.1.3.1-1). Though the activities of each target species and life stage are variable and could expand beyond the dates delineating specific bioperiods, the date ranges described for each bioperiod would be expected to encompass their primary needs (Figure 4.1.3.1-1 and Table 4.1.3.1-1). The aquatic habitat needs within each bioperiod were assessed as follows:

Winter Survival

Flows during the winter on the Warner River tend to be moderate. Relatively little is known about winter habitat use by aquatic organisms; however, wetted area is generally considered to be important for a variety of aquatic life (AEFOC, 2007). Therefore, habitat timeseries analyses were performed on wetted area provided by the habitat-hydraulic model.

Freshet

Springtime snowmelt and rains result in high flows during the freshet. During this period, most aquatic species would be seeking velocity refugia, and individuals of some species would begin moving toward spawning areas. High flows and associated inundation during the freshet are also important for riparian and wetland habitats. Habitat timeseries analyses during the freshet were performed using the water level at the USGS gage, which was back-calculated for the full timeseries based on a rating curve developed for the gage.

Springtime Anadromous and Resident Cyprinid Spawning

If unimpeded by downstream dams, river herring could be found in the lower portions of the Warner River beginning in May, with shad arriving slightly later, and spawning and incubation would be expected to occur from shortly after their arrival through the month of June, with river herring completing their spawning before shad. Sea lamprey would also be expected to spawn within the river within the same timeframe. This spawning period also coincides with resident cyprinid species that prefer similar water temperatures and conditions for spawning, such as longnose dace and fallfish.

Rearing and Growth

Adult and juvenile resident fish, along with juvenile diadromous fish, where present, would typically feed and grow during the summer period when flows are relatively low. Habitat timeseries analyses were performed on a variety of relevant species and life stages.

Fall Salmonid Spawning

Atlantic salmon[13] were the dominant species in the TFC for the Warner River. This species spawns in the fall in October and November.

[13] Though Atlantic Salmon are no longer documented utilizing the Warner River, they were included in this assessment because the flows they required could also be used by other species as part of the natural flow paradigm.

Table 4.1.3.1-1: Warner River Bioperiod Date Ranges

Bioperiod	Start Date	End Date	Days in Period
Winter Survival[14]	12/1	2/28	90
Freshet	3/1	4/30	61
Springtime Anadromous and Resident Cyprinid Spawning	5/1	6/30	61
Rearing and Growth	7/1	9/30	92
Fall Salmonid Spawning	10/1	11/30	61

[14] The winter survival period would end on February 29 and would span 91 days during leap years. Additionally, if the spring freshet occurs late, the flows needed for the Winter Survival period could continue until flows increase due to the freshet.

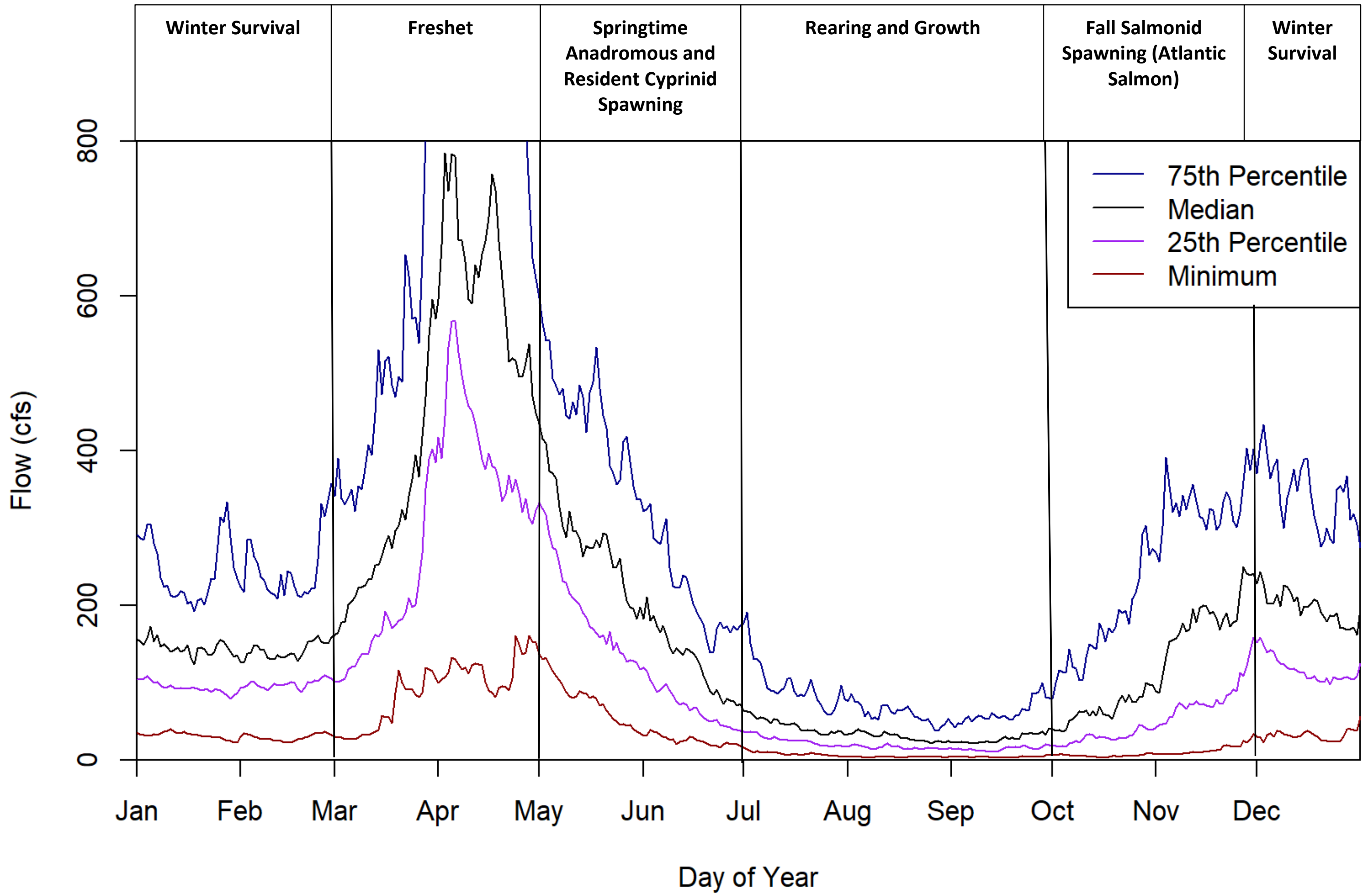


Figure 4.1.3.1-1: Warner River Flow Statistics and Bioperiods

4.1.3.2 UCUT Analyses

UCUT curves were developed based on the habitat-flow relationships and the flow timeseries. UCUT curves for several of the species and lifestages from the TFC were considered suitable for the Protected Instream Flow analysis (Table 4.1.3.2-1). However, some were excluded from further analysis because they were also limited by high flows during the bioperiod that they were selected to represent. The UCUT curves are included in Appendix G. The results of the UCUT analyses for each species and bioperiod are shown in Tables 4.1.3.2-1 to 4.1.3.2-6.

Each of the tables provides habitat stressor thresholds derived from the UCUT curves. These thresholds include the magnitude (e.g., % wetted area, % WUA, gage height) of common, critical and rare habitat limitation events, along with their persistent and catastrophic durations, as defined in Section 3.1.8.4. The corresponding flows associated with the habitat stressor thresholds are also included for each threshold. After analysis of individual species, the habitat stressor thresholds were consolidated for the various species in each bioperiod (see Section 4.1.4).

Table 4.1.3.2-1: Summary of UCUT Analyses

Applicable Bioperiod	Target Species or Parameter	Life Stage[15]	UCUT Results Evaluated	Comments
Winter	Wetted Area	Aquatic Habitats	Yes	No comments
Freshet	Gage Height	Riparian Habitats	Yes	No comments
Springtime Anadromous and Resident Cyprinid Fish Spawning	American shad	Spawning	Yes	No comments
Springtime Anadromous and Resident Cyprinid Fish Spawning	river herring	Spawning	No	High flows were more limiting than low flows
Springtime Anadromous and Resident Cyprinid Fish Spawning	sea lamprey	Spawning	Yes	No comments
Springtime Anadromous and Resident Cyprinid Fish Spawning	longnose dace	Spawning	No	High flows were more limiting than low flows
Springtime Anadromous and Resident Cyprinid Fish Spawning	fallfish	Spawning	No	High flows were more limiting than low flows
Rearing/Growth	longnose dace	Adult	Yes	No comments
Rearing/Growth	longnose dace	Juvenile	No	High flows were more limiting than low flows
Rearing/Growth	blacknose dace	Adult	Yes	No comments
Rearing/Growth	fallfish	Adult	Yes	No comments
Rearing/Growth	fallfish	Juvenile	Yes	No comments
Rearing/Growth	Atlantic salmon	Juvenile (parr)	No	High flows were more limiting than low flows
Rearing/Growth	American shad	Juvenile	Yes	No comments
Fall Salmonid Spawning	Atlantic salmon	Spawning	Yes	No comments

[15] Note: Young-of-year (YOY)/Fry were not included in this assessment because their habitat is not typically limited by low flows. Further, fry develop into YOY/juvenile fish relatively quickly and any applicable bioperiod would be too short (and variable in time) for effective management.

Table 4.1.3.2-2: UCUT Results for Winter Bioperiod

Threshold	Wetted Area
Common Habitat (%WUA)	**98%**
Common Persistent Duration (days)	45
Common Catastrophic Duration (days)	77
Common Corresponding Flow (cfs)	317
Critical Habitat (%WUA)	**88%**
Critical Persistent Duration (days)	22
Critical Catastrophic Duration (days)	40
Critical Corresponding Flow (cfs)	80
Rare Habitat (%WUA)	**84%**
Rare Persistent Duration (days)	10
Rare Catastrophic Duration (days)	16
Rare Corresponding Flow (cfs)	39

Table 4.1.3.2-3: UCUT Results for Freshet Bioperiod

Threshold	USGS Gage
Common Habitat (%WUA)	**6.4 ft**
Common Persistent Duration (days)	26
Common Catastrophic Duration (days)	44
Common Corresponding Flow (cfs)	1,062
Critical Habitat (%WUA)	**4.2 ft**
Critical Persistent Duration (days)	13
Critical Catastrophic Duration (days)	27
Critical Corresponding Flow (cfs)	148
Rare Habitat (%WUA)	**4.0 ft**
Rare Persistent Duration (days)	7
Rare Catastrophic Duration (days)	11
Rare Corresponding Flow (cfs)	109

Table 4.1.3.2-4: UCUT Results for Springtime Anadromous Fish and Resident Cyprinid Spawning

Threshold	American Shad Spawning	Sea Lamprey Spawning
Common Habitat (%WUA)	**88%**	**84%**
Common Persistent Duration (days)	15	15
Common Catastrophic Duration (days)	37	32
Common Corresponding Flow (cfs)	244	166
Critical Habitat (%WUA)	**50%**	**38%**
Critical Persistent Duration (days)	7	9
Critical Catastrophic Duration (days)	11	13
Critical Corresponding Flow (cfs)	44	45
Rare Habitat (%WUA)	**42%**	**30%**
Rare Persistent Duration (days)	4	6
Rare Catastrophic Duration (days)	6	9
Rare Corresponding Flow (cfs)	31	32

Table 4.1.3.2-5: UCUT Results for Rearing and Growth Bioperiod

Threshold	Longnose Dace Adult	Blacknose Dace Adult	Fallfish Adult	Fallfish Juvenile	American Shad Juvenile
Common Habitat (%WUA)	**88%**	**84%**	**88%**	**92%**	**88%**
Common Persistent Duration (days)	21	30	30	30	25
Common Catastrophic Duration (days)	57	71	65	65	83
Common Corresponding Flow (cfs)	46	76	59	57	77
Critical Habitat (%WUA)	**28%**	**30%**	**38%**	**28%**	**44%**
Critical Persistent Duration (days)	11	15	14	14	16
Critical Catastrophic Duration (days)	20	24	26	24	32
Critical Corresponding Flow (cfs)	8	11	11	11	11
Rare Habitat (%WUA)	**18%**	**22%**	**24%**	**16%**	**30%**
Rare Persistent Duration (days)	8	8	8	8	8
Rare Catastrophic Duration (days)	15	16	15	15	15
Rare Corresponding Flow (cfs)	5	6	6	5	6

Table 4.1.3.2-6: UCUT Results for Fall Salmonid Spawning Bioperiod

Threshold	Atlantic Salmon Spawning
Common Habitat (%WUA)	**78%**
Common Persistent Duration (days)	20
Common Catastrophic Duration (days)	39
Common Corresponding Flow (cfs)	106
Critical Habitat (%WUA)	**4%**
Critical Persistent Duration (days)	11
Critical Catastrophic Duration (days)	22
Critical Corresponding Flow (cfs)	29
Rare Habitat (%WUA)	**2%**
Rare Persistent Duration (days)	8
Rare Catastrophic Duration (days)	15
Rare Corresponding Flow (cfs)	23

4.1.4 Protected Instream Flow Recommendations for Aquatic Habitat

Based on the UCUT results in Section 4.1.3.2, Protected Instream Flow thresholds and durations were determined by selecting the values that would be protective of habitat for most or all species assigned to a bioperiod (Table 4.1.4-1). The most protective habitat thresholds were represented by higher flows and/or lower durations of habitat limitation events for the species in a bioperiod. The protected instream flows for aquatic habitat are provided in Table 4.1.4-2.

Table 4.1.4-1: Summary of Species/Parameters that Defined the Protected Instream Flows

Bioperiod	Common	Critical	Rare
Winter Survival	Wetted Area	Wetted Area	Wetted Area
Freshet	Gage Height	Gage Height	Gage Height
Springtime Anadromous and Resident Cyprinid Spawning	American Shad Spawning	American Shad Spawning	American Shad Spawning
Rearing and Growth	Blacknose Dace Adult	Fallfish Juvenile	Several Species
Fall Salmonid Spawning	Atlantic Salmon Spawning	Atlantic Salmon Spawning	Atlantic Salmon Spawning

Table 4.1.4-2: Protected Instream Flows for Aquatic Habitat in the Warner River

	Common	Common	Common	Common	Critical	Critical	Critical	Critical	Rare	Rare	Rare	Rare
Bioperiod	**Common Flow (cfs)**	**Common Flow (cfsm)**	**Allowable Duration Under (days)**	**Catastrophic Duration (days)**	**Critical Flow (cfs)**	**Critical Flow (cfsm)**	**Allowable Duration Under (days)**	**Catastrophic Duration (days)**	**Rare Flow (cfs)**	**Rare Flow (cfsm)**	**Allowable Duration Under (days)**	**Catastrophic Duration (days)**
Winter Survival	317	2.17	45	77	80	0.55	22	40	39	0.27	10	16
Freshet	1,062	7.27	26	44	148	1.01	13	27	109	0.75	7	11
Springtime Anadromous and Resident Cyprinid Fish Spawning	244	1.67	15	37	44	0.30	7	11	31	0.21	4	6
Rearing and Growth	76	0.52	30	71	11	0.08	14	24	6	0.04	8	15
Fall Salmonid Spawning	106	0.73	20	39	29	0.20	11	22	23	0.16	8	15

Note: Flows provided are for the USGS gage at Davisville, NH (USGS Gage No. 01086000)

Key:
Green shaded column means Common.
Yellow shaded columns mean Critical.
Peach shaded columns mean Rare.

4.2 Riparian Habitat

4.2.1 Floodplain Transect Method Results

A total of six transects (Table 4.2.1-1 and Figure 4.1.1.1-1) were evaluated using the FTM. Riparian transects were surveyed from September 13 to September 15, 2021, when river flow at the USGS gage was between 118 cfs and 156 cfs. Water level loggers were installed September 1, 2021 and were removed on June 1, 2022[16]. Individual measurements of water surface elevation were made in November 2021 and March 2022 using a Total Station to calibrate and verify data from the loggers.

Table 4.2.1-2 shows the relationship between flows at the USGS gage and the observed inundation of plant communities in the river channel and riparian floodplain at the six transect locations. Cross-section plots are included in Appendix H.

[16] No power remained in the batteries on/after April 27, 2022 resulting in the data set ending on that date.

Table 4.2.1-1: Summary of Transects for the Floodplain Transect Method

Transect ID	Transect Location	Reach	Protected Entities Represented
T1	0.4 river miles downstream of the Route 114 bridge in Bradford	1	PSS1, PSS2, PEM1Af – scrub-shrub wetlands dominated by silky dogwood and speckled alder, emergent wetlands dominated by goldenrod and aster.
T2	0.1 river miles downstream of the Lane River confluence in Sutton	2b	PSS1C, PSS1F, R3AB3– semi-permanently and seasonally-flooded scrub-shrub wetlands dominated by silky dogwood, willow, nannyberry, and speckled alder. Riverine wetlands with bur-reed, floating pondweed, bladderwort, and smartweed.
T3	0.4 river miles downstream of the most upstream I-89 bridge in Warner	3	PSS1F – semi-permanently flooded scrub-shrub wetland dominated by buttonbush, speckled alder, and silky dogwood.
T4	0.25 river miles downstream of West Joppa Road covered bridge	3	PEM2, PSS1, PUB3 – emergent wetlands dominated by water smartweed, pickerel weed, bladderwort, rice cut grass, broad-leaved cat-tail, and common soft rush. Scrub-shrub wetland dominated by willow, silky dogwood, and sensitive fern. Backwater slough with sensitive fern.
T5	In between north and south bound lanes of I-89 in Warner, 0.2 river miles downstream of north bound lane bridge.	3	PFO1, PSS1 – floodplain forests dominated by American sycamore, American hornbeam, red maple, American elm, and American linden. Shrub-scrub wetlands dominated by fox grape, silky dogwood, honeysuckle, nannyberry, sensitive fern, and Virginia creeper.
T6	0.5 river miles downstream of rail bridge on rail trail in Bagley Park	4a	PFO1, PEM2 – floodplain forests, some seasonally-flooded, dominated by silver maple, red maple, gray birch, American elm, and sensitive fern. Emergent wetlands dominated by smartweed, deer-tongue, arrow-leaved tearthumb, swamp yellow-loosestrife, heath American-aster, small cranberry, reed canary grass, sensitive fern, Canada goldenrod.

Table 4.2.1-2: Flows Associated with Observed Inundation of Community Types

Transect	Plant Community in Order by Ascending Elevation[17]	Flow (cfs) that Inundates Community	Percent of time flow is equaled or exceeded
Transect 1	PSS1 and PEM1Af	845 cfs	5%
Transect 1	PSS1 and PFO1	1,120 cfs	3%
Transect 1	Left bank upland	1,290 cfs	2%
Transect 1	Right bank upland	> 1,560 cfs	< 2%
Transect 2	R3AB3	330 cfs	24%
Transect 2	PSS1C and PSS1F	633 cfs	9%
Transect 2	PSS1	1,140 cfs	3%
Transect 2	PFO1A and Upland	> 1,560 cfs	< 2%
Transect 3	PEM2	800 cfs	6%
Transect 3	Left bank PFO1 and PSS1F	1,100 cfs	3%
Transect 3	Left bank upland and PFO1	1,300 cfs	2%
Transect 3	Right bank PFO1, PFO1/PSS1, PSS1, and Upland	> 1,560 cfs	< 2%
Transect 4	PEM2 and PSS1	400 cfs	19%
Transect 4	PFO1	1,010 cfs	4%
Transect 4	PFO1A and PUB3	1,290 cfs	2%
Transect 4	Upland	> 1,560 cfs	< 2%
Transect 5	PSS1 and PEM2 (Channel bar)	560 cfs	12%
Transect 5	Right bank PFO1's, PSS1, and Upland	1,060 cfs	4%
Transect 5	Left bank PFO1's, PSS1's, and Upland	1,160 cfs	3%
Transect 6	PEM2 (Side of channel bar)	300 cfs	27%
Transect 6	Left bank PFO1's, PSS1, and PUB3	1,300 cfs	2%
Transect 6	Right bank PFO1/PSS1, PFO1F, PEM1's, PFO1's, and Upland	1,500 cfs	< 2%

[17] See Appendix A for wetland classification definitions.

4.2.2 Protected Instream Flow Recommendations for Riparian/Wetland Habitats

All of the documented scrub-shrub, emergent, and lower elevation seasonally-/semi-permanently flooded floodplain forests were inundated at some level during the study period, aside from the right overbank at T3, which was fairly steep. Emergent side channel bars at T2, T4, and T6 are inundated at flows between 300 cfs and 400 cfs, which typically occur multiple times per year on the Warner River. Overbank areas containing floodplain forests and scrub-shrub wetlands are inundated at flows between 1,010 cfs and 1,160 cfs, which is consistent with the magnitude of a 1-year flood event. Several higher elevation floodplain forests were observed to be inundated at the highest flows observed during the study period, from 1,290 cfs to 1,500 cfs. Flows consistent with a 2-year flood event (2,225 cfs) would inundate these habitats.

4.3 Recreation

Two whitewater paddlers were surveyed during the recreation survey visits on May 1, 2021, when flow at the USGS gage was approximately 565 cfs. Both paddlers were paddling the run from Melvin Mills to West Roby District Road and had paddled it many times that day. Both indicated that they typically paddle the Warner River in spring, and one indicated that they sometimes paddle in the fall. Both indicated that flows between 565 cfs and 600 cfs were ideal and flows up to 800 cfs were boatable. Neither had an exact indication of the lowest flow, but one stated that below 565 cfs would not be preferable. Results from the search of the MVP Facebook page indicate similar flow preferences. Most people in the group that posted about boating the Warner River did so between 400 cfs and 800 cfs, with a median flow of 596 cfs.

Based on the results of the recreational surveys, swimming was not determined to be a flow-dependent resource on the Warner River. Anglers were not surveyed during recreational surveys; however, several anglers were noted during other field efforts. Angling was observed during the late spring and summer months. No direct flow preference data from anglers was obtained during the study period. Habitat for aquatic species is likely more of a limiting factor to longer-term angling success than the needs of anglers. Given the substantial data on aquatic habitat, and the relatively limited information on flow needs for angling, no protected instream flow recommendations were provided for angling. Instead, flow recommendations during the summer period were derived from the needs of aquatic habitat. The natural flow paradigm will provide the necessary aquatic habitat to allow angling activities to occur on the Warner River.

5 Discussion

Based on this study, Protected Instream Flows for the Warner River (Table 5-1) are based on the needs of aquatic habitat, riparian habitat, and paddling. Other public uses of the stream are either not flow-dependent, or their needs would be satisfied by the recommendations for aquatic and riparian habitat. Protected instream flows for aquatic habitat would protect against extended periods of low flows, which could be exacerbated by water withdrawals or diversions during low flow periods. Additionally, providing flow frequencies in accordance with the natural flow paradigm would protect instream flows for riparian habitat and recreation.

Table 5-1: Protected Instream Flows for the Warner River[18]

	Common	Common	Common	Common	Critical	Critical	Critical	Critical	Rare	Rare	Rare	Rare
Date Range	**Common Flow (cfs)**	**Common Flow (cfsm)**	**Allowable Duration Under (days)**	**Catastrophic Duration (days)**	**Critical Flow (cfs)**	**Critical Flow (cfsm)**	**Allowable Duration Under (days)**	**Catastrophic Duration (days)**	**Rare Flow (cfs)**	**Rare Flow (cfsm)**	**Allowable Duration Under (days)**	**Catastrophic Duration (days)**
December 1 – February 28/29	317	2.17	45	77	80	0.55	22	40	39	0.27	10	16
March 1 – April 30	1,062	7.27	26	44	148	1.01	13	27	109	0.75	7	11
May 1 – June 30	244	1.67	15	37	44	0.30	7	11	31	0.21	4	6
July 1 – September 30	76	0.52	30	71	11	0.08	14	24	6	0.04	8	15
October 1 – November 30	106	0.73	20	39	29	0.20	11	22	23	0.16	8	15

Retain Flood Frequencies:

- Inter-annual flow events of at least 400 cfs multiple times per year for emergent and riverine wetlands
- Annual flood frequency of at least 1,160 cfs for shrub scrub and seasonally/semi-permanently flooded floodplain forests
- 2-year flood frequency of at least 2,225 cfs for higher elevation floodplain forests

Optimum Recreational Boating Flows (Spring and Fall): Provide flow events of 565 cfs to 800 cfs.

Key:
Green shaded column means Common.
Yellow shaded columns mean Critical.
Peach shaded columns mean Rare.

[18] Note: Flows provided are indexed to the USGS gage at Davisville, NH (USGS Gage No. 01086000), drainage area of 146 mi^2

6 References

Aadland, L.P., Kuitunen, A. (1991). Habitat Suitability Criteria for Stream Fishes and Mussels of Minnesota. Minnesota Department of Natural Resources Ecological Services Division.

AEFOC. 2007. Water Management Framework: Instream Flow Needs and Water Management System for the Lower Athabasca River. February 2007.

Bain, M. and Meixler, M., 2005. Defining a Target Fish Community for Planning and Evaluating River Rehabilitation. Environmental Biology of Fishes.

Bovee, K., 1982. A Guide to Stream Habitat Analysis Using the Instream Flow Incremental Methodology. Office of Biological Service FWS/OBS-82-26.

Capra, H., Breil, P. and Souchon, Y., 1995. A new tool to interpret magnitude and duration of fish habitat variations. Regulated Rivers: Research & Management, 10(2-4), pp.281-289.

Cowardin, L., et al., 1979. Classification of Wetlands and Deepwater Habitats of the United States. FWS/OBS – 79/31.

Edwards, E., 1983. Habitat Suitability Index Models: Longnose Dace. USFWS Bluebook. Modified by VDFW.

Fennessey, N.M. 2018a. A Final Report on the Update of a Regional Streamflow Duration Curve Model for the Northeast United States and the Generation of Estimated Daily Flows Using the QPPQ Transform Method at Ungaged Sites in New Hampshire. HYSR. Prepared for the New Hampshire Department of Environmental Services, March.

Fennessey, N.M. 2018b. A Final Report on the Further Assessment of the QPPQ Transform Method for Estimating Daily Streamflow at Ungaged Sites in New Hampshire. HYSR. Prepared for the New Hampshire Department of Environmental Services, August.

Fennessey, N.M. 2019. Extending the Daily Streamflow Period-of-Record at the USGS Gage site on the Cold Rivera and the USGS Gage Site on the Warner River. NHDES-R-WD-19-03.

US EPA. 2021. Why are Wetlands Important?| US EPA. [online] [Accessed 27 October 2022].

GoBotany Native Plant Trust. Gobotany – Native Plant Trust. [Accessed 27 October 2022].

Gomez and Sullivan. 2018. Statewide Target Fish Community Assessment. Warner River. Final Report.

Kynard, B. and Horgan, M., 2013. Habitat Suitability Index for Sea Lamprey Redds. BK-Riverfish, LLC. Modified per USFWS in 2014.

NHDAMF. 2017. Fact Sheet: Prohibited Invasive Plant Species Rules, Agr 2800. [online] [Accessed 27 October 2022].

NHDES. 2009. Comparison of Floodplain Transect and Remote Sensing Methods for the Lamprey River Instream Flow Project. Prepared by Normandeau Associates, Inc. and Rushing Rivers Institute. R-WD-09-9.

NHDES. 2015. Report of the Instream Flow Pilot Program. Prepared by Watershed Management Bureau, NH Department of Environmental Services. R-WD-15-1.

NHDFL. 2020. New Hampshire Official Rare Plant List. [online] Nh.gov. Available at: Ncr 312 (nh.gov) [Accessed 27 October 2022].

NHDFL. [online]. Available at Natural Communities | Reports | NH Division of Forests and Lands [Accessed 27 October 2022]

NHFG. Eastern elliptio. [online] Available at Eastern elliptio | Nongame | New Hampshire Fish and Game Department (state.nh.us). [Accessed March 2022].

Pardue, G., 1983. Habitat Suitability Index Models: Alewife and Blueback Herring. USFWS Bluebook.

Poff, N.L., Allan, J.D., Bain, M.B., Karr, J.R., Prestegaard, K.L., Richter, B.D., Sparks, R.E., and J.C. Stromberg., 1997. The Natural Flow Regime: A Paradigm for River Conservation and Restoration. BioScience 47(11): 769-784.

Sperduto, D. and Nichols, W., 2012. Natural Communities of New Hampshire Second Edition. [online] Nh.gov. Available at: WebVersion_Tech Manual (nh.gov) [Accessed 27 October 2022].

Stanley, J., Trial, J., 1995. Habitat Suitability Index Models: Nonmigratory Freshwater Life Stages of Atlantic Salmon. National Biological Service Biological Science Report 3.

Stier, D., Crance, J., 1985. Habitat Suitability Index Models and Instream Flow Suitability Curves: American Shad. USFWS Bluebook.

Trial, J., Stanley, J., 1983. Habitat Suitability Information: Blacknose Dace. USFWS Bluebook.

USDOI and USGS. 2001. PHABSIM for Windows User's Manual and Exercises. Midcontinent Ecological Science Center. Open File Report 01-340.

Warner River Local Advisory Committee (WRLAC). 2021. Warner River Corridor Management Plan. Prepared by WRLAC with assistance from the Central NH Regional Planning Commission. January 2021. R-WD-20-25.